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REPORT

OF THE

SIXTY-SECOND MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

EDINBURGH IN AUGUST 1892.

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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive

gratuitously the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis;* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.
   New Life Members who have paid Ten Pounds as a composition.
   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.
   Annual Members who have intermitted their Annual Subscription.
   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s.* 6*d.* per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

Class B. Temporary Members.[1]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports

[1] Revised by the General Committee, 1884.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting.* It has therefore become

thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the Sectional Committee, after which their functions as an Organising Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, for the objects stated in the Rules of the Association, and specified below. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee [*see* p. xc].

The business is to be conducted in the following manner :—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the

necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before....., addressed to the General Secretaries, at the office of the Association. 'For Section.....' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Secretary, *before the conclusion of the Meeting.*

[1] Sheffield, 1879. [2] Swansea, 1880. [3] Edinburgh, 1871.

[4] The meeting on Saturday is optional, Southport, 1883.

Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxxii), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and*

[1] These rules were adopted by the General Committee, Plymouth, 1877.

[2] This and the following sentence were added by the General Committee, Edinburgh, 1871.

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[2]

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Chairman of a Committee to whom a money grant has been made must forward to the General Officers, before July 1, a statement of the sums which have been expended, with vouchers, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire on June 30 following; nor is the Treasurer authorised, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General

[1] Revised by the General Committee, Bath, 1888.
[2] Passed by the General Committee at Sheffield, 1879.

Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Chairman is the only person entitled to call on the Treasurer, Professor A. W. Rücker, F.R.S., Burlington House, London, W., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and Sectional Committee. Passed by the General Committee at Edinburgh, 1892.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

Presidents of the Association in former years are *ex officio* members of the Committee of Recommendations.[1]

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[2]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant General Secretary.[3]

Corresponding Societies.[4]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Secretary of the Association, a schedule, properly filled up, which will be issued by the Secretary of the Association, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association

[1] Passed by the General Committee at Newcastle, 1863.
[2] Passed by the General Committee at Birmingham, 1865.
[3] Passed by the General Committee at Leeds, 1890.
[4] Passed by the General Committee, 1884.

a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of [1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting.
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year —observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditor appointed by the General Committee.

[1] Passed by the General Committee, Belfast, 1874.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. York, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. Oxford, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. Cambridge, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. Edinburgh, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. Dublin, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. Bristol, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London Liverpool, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. Newcastle-on-Tyne, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. Birmingham, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. Glasgow, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. Plymouth, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. Manchester, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. Cork, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. York, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S Professor Fuller, M.A. John F. White, Esq.

The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.

PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S..... LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S..... Sir Philip de Malpas Grey Egerton, Bart., M.P..... The Right Hon. W. E. Gladstone, D.C.L., M.P..... S. R. Graves, Esq., M.P..... Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S..... James P. Joule, Esq., LL.D., D.C.L., F.R.S..... Joseph Mayer, Esq., F.S.A., F.R.G.S.....	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E..... EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S..... The Right Hon. the Lord Provost of Edinburgh ..... The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland.. Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh..... Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S..... Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. ..... Dr. Lyon Playfair, C.B., M.P., F.R.S. ..... Professor Christison, M.D., D.C.L., Pres. R.S.E. ..... Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S... BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk..... His Grace the Duke of Richmond, K.G., P.C., D.C.L. ..... His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. ..... Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. ..... Dr. Sharpey, LL.D., Sec. R.S., F.L.S. ..... Joseph Prestwich, Esq., F.R.S., Pres. G.S.....	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S..... BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. ..... The Right Hon. Lord Houghton, D.C.L., F.R.S..... The Right Hon. W. E. Forster, M.P. ..... The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S... J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S..	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. ..... BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. ..... The Right Hon. the Earl of Rosse, F.R.S. ..... Sir Richard Wallace, Bart., M.P. ..... The Rev. Dr. Henry. Dr. Andrews, F.R.S..... The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.....	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. .. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. ..... The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S.... The Mayor of Bristol ..... Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S..... W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S. L. & E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.

C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., Ph.D., LL.D., F.R.S.L. & E., F.C.S. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau. Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B. M.P., Ph.D., LL.D., F.R.S. L. & E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S. L. & E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon the Earl of Cork and Orrery, Lord Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. — Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. — Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.

SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon. M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S., F.C.S. The Right Hon. W. L. Jackson, M.P., F.S.S. The Right Worshipful the Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E., F.R.G.S. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A., F.C.S. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc., F.C.S.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S., F.R.G.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S., Director-General of the Geological Survey of the United Kingdom Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

1832. Oxford.....	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

1835. Dublin.....	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol.....	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S.....	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.....	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.....	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.....	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford.....	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.....	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast.....	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.....	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.

Date and Place	Presidents	Secretaries
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1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin.....	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford.....	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.....	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter.....	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast.....	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol.....	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin.....	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.

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1881. York.....	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Prof. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, Prof. A. Johnson, Prof. O. J. Lodge, Dr. D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath.....	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff.....	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford.....	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope.....	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin.....	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol.....	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.....	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.....	Prof. Apjohn, M.R.I.A.....	R. Hunt, Dr. Sweeny.
1844. York.....	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.

Date and Place	Presidents	Secretaries
1847. Oxford.....	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.....	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast.....	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin.....	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford.....	Prof. B. C. Brodie, F.R.S.....	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.....	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast.....	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, Dr. W. R. Eaton Hodgkinson, J. M. Thomson.
1881. York.....	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S., F.C.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.....	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, Dr. H. Forster Morley, R. E. Moyle, Dr. W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S.	Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol.
1891. Cardiff.....	Prof. W. C. Roberts-Austen, C.B., F.R.S., F.C.S.	C. H. Bothamley, Dr. H. Forster Morley, Dr. W. W. J. Nicol, Dr. G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S., F.C.S.	Dr. J. Gibson, Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford.....	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin.....	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol.....	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.

Date and Place	Presidents	Secretaries
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.....	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.....	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.
1847. Oxford.....	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast.....	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.....	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford.....	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.....	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section,"' for Presidents and Secretaries of which see page lxi.

Date and Place	Presidents	Secretaries
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast.....	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J.Armstrong,F.W.Rudler,W.Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin.....	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York.....	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.....	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford.....	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham.....	W. Yarrell, Prof. Burnett.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lx.

Date and Place	Presidents	Secretaries
SECTION D.—ZOOLOGY AND BOTANY.		
1835. Dublin	Dr. Allman	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow	Sir W. J. Hooker, LL.D.	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.
SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.		
[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lx.]		
1848. Swansea	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool	Prof. Balfour, M.D., F.R.S.	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.

Date and Place	Presidents	Secretaries
1864. Bath.....	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

1866. Nottingham	Prof. Huxley, LL.D., F.R.S.—*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S.—*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S.—*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter.....	George Busk, F.R.S., F.L.S.—*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh.	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast.....	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S.—*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.....	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S. — *Dep. of Zool. and Bot.*, Prof. M. A. Lawson, M.A., F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, M.A., F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport [1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal [2]...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. McIntosh, M.D., LL.D., F.R.S. F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.

[1] By direction of the General Committee at Southampton (1882) the Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] By authority of the General Committee, Anthropology was made a separate Section, for Presidents and Secretaries of which see p. lxvii.

Date and Place	Presidents	Secretaries
1888. Bath.....	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, Dr. S. J. Hickson, Prof. F. W. Oliver, H. Wager, Prof. H. Marshall Ward.
1891. Cardiff.....	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, Prof. W. Stirling, H. Wager.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. Haviland.....	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard.....	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York.....	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin.....	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lvii.). Section E, being then vacant, was assigned in 1851 to Geography.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford.....	Prof.G.Rolleston,M.D.,F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D.....	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.....	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[1]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. liv.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard.....	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	.....	G. Grant Francis.
1849. Birmingham	.....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast.....	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.....	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin.....	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford.....	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.....	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.....	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.....	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.

[1] *Vide* note on page lviii.

Date and Place	Presidents	Secretaries
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, Clements R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.
	SECTION E (*continued*).—GEOGRAPHY.	
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S.....	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast.....	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol.....	Lieut.-General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.....	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin.....	Prof. Sir C. Wyville Thomson, LL.D., F.R.S. L.&E	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.....	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.....	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff.....	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

Date and Place	Presidents	Secretaries
1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.....	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol.....	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.....	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.....	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford.....	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton.....	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast.....	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.....	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch. Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin.....	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers.....	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast.....	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.....	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, Prof. J. E. C. Munro, G. H. Sargant.
1888. Bath.....	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, Prof. H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.

Date and Place	Presidents	Secretaries
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.....	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.....	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.

Date and Place	Presidents	Secretaries
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee.....	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.....	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast.....	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.....	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport	James Brunlees, F.R.S.E., Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.....	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S. F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff.....	T. Forster Brown, M.Inst.C.E.,	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.

ANTHROPOLOGICAL SCIENCE.

SECTION H.—ANTHROPOLOGY.

Date and Place	Presidents	Secretaries
1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath.....	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas.R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff.....	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.

LIST OF EVENING LECTURES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.....	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison.....	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.....	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.....	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson.....	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.....	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford.....	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.....	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.....	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.

Date and Place	Lecturer	Subject of Discourse
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast.....	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull.....	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.....	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.....	Correlation of Physical Forces.
1857. Dublin.....	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford.....	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.....	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.....	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.....	The Balloon Ascents made for the British Association.
1864. Bath.....	Prof. Roscoe, F.R.S.....	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.....	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.....	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.....	Insular Floras.
1867. Dundee.....	Archibald Geikie, F.R.S.....	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.

Date and Place	Lecturer	Subject of Discourse
1868. Norwich ...	J. Fergusson, F.R.S.....	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.....	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer F.R.S....	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.....	Some recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast.....	Sir John Lubbock, Bart..M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S.....	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.....	The new Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.....	Animal Intelligence.
	Prof. Dewar, F.R.S.....	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S.....	Mental Imagery.
1881. York.....	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S.	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick, F.R.S.E.	Galvanic and Animal Electricity.
1884. Montreal...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E.....	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton, K.C.M.G.	Explorations in Central Africa.

Date and Place	Lecturer	Subject of Discourse
1888. Bath.....	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.....	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. Milnes Marshall, D.Sc., F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S., F.R.S.E.	Magnetic Induction.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee.....	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental Illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S.....	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece.....	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York.....	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.....	Comets.
1885. Aberdeen...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath.....	Sir John Lubbock, Bart., M.P., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.

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THE BRITISH ASSOCIATION FOR

Dr. THE GENERAL TREASURER'S ACCOUNT

1891–92. RECEIPTS.

	£	s.	d.
Balance brought forward	846	1	2
New Life Compositions at Cardiff Meeting and since	330	0	0
New Annual Members' Subscriptions at Cardiff Meeting and since	318	0	0
Annual Subscriptions " "	555	0	0
Sale of Associates' Tickets at Cardiff	672	0	0
Sale of Ladies' Tickets at Cardiff	107	0	0
Sale of Publications	233	2	8
Rent from Mathematical Society for the year ending September 29, 1891	12	15	0
Interest on Exchequer Bills	13	8	2
Dividends on Consols	170	18	9
Dividends on India 3 per cents.	78	19	6
Unexpended Balance of Grant made 'for improving a Deep-sea Tow-net'	27	14	6
	£3364	19	9

Investments.

	£	s.	d.
New Consols	8500	0	0
India 3 per cents.	3600	0	0
Exchequer Bills	500	0	0
	£12600	0	0

THE ADVANCEMENT OF SCIENCE.

(from August 1, 1891, to June 30, 1892). *Cr.*

1891-92. PAYMENTS.

	£	s.	d.
Expenses of Cardiff Meeting, including Printing and Advertising, payment of Clerks, &c.	141	3	9
Rent and Office Expenses, including Furniture, &c.	196	19	8
Salaries	312	10	0
Messrs. Spottiswoode & Co., printing, binding, &c.	1321	7	10

GRANTS.

	£	s.	d.			
Meteorological Observations on Ben Nevis	50	0	0			
Photographs of Meteorological Phenomena	15	0	0			
Pellian Equation Tables	10	0	0			
Discharge of Electricity from Points	50	0	0			
Seismological Phenomena of Japan	10	0	0			
Formation of Haloids	12	0	0			
Properties of Solutions	10	0	0			
Action of Light on Dyed Colours	10	0	0			
Erratic Blocks	15	0	0			
Photographs of Geological Interest	20	0	0			
Underground Waters	10	0	0			
Investigation of Elbolton Cave	25	0	0			
Excavations at Oldbury Hill	10	0	0			
Cretaceous Polyzoa	10	0	0			
Table at Naples Zoological Station	100	0	0			
Table at Plymouth Biological Laboratory	17	10	0			
Improving a Deep-sea Tow-net	40	0	0			
Fauna of Sandwich Islands	100	0	0			
Zoology and Botany of West India Islands	100	0	0			
Climatology and Hydrography of Tropical Africa	50	0	0			
Anthropometric Laboratory	5	0	0			
Anthropological Notes and Queries	20	0	0			
Prehistoric Remains in Mashonaland	50	0	0			
North-Western Tribes of Canada	100	0	0			
Corresponding Societies	25	0	0			
				864	10	0
By Balance at Bank of England, Western Branch	436	18	6			
Less Cheques drawn but not presented	119	10	0			
	317	8	6			
In hands of General Treasurer	11	0	0			
				328	8	6
				£3364	19	9

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JOHN B. MARTIN, }

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.....	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.....	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton.....	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.....	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.....	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ..	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds.....	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.....	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.....	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23 ...	Southampton	Dr. C. W. Siemens, F.R.S.....	178	17
1883, Sept. 19 ...	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27 ...	Montreal	Prof. Lord Rayleigh, F.R.S. ...	235	20
1885, Sept. 9 ...	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1 ...	Birmingham.....	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31 ...	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5 ...	Bath	Sir F. J. Bramwell, F.R.S.....	266	36
1889, Sept. 11 ...	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3 ...	Leeds.....	Sir F. A. Abel, C.B., F.R.S. ...	259	21
1891, Aug. 19 ...	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3 ...	Edinburgh	Sir A. Geikie, LL.D., F.R.S. ...	280	14

* Ladies were not admitted by purchased Tickets until 1843. † Tickets of Admission to Sections only

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
...	...	...	...	...	353	.....	.....	1831
...	...	...	...	...	...	.....	.....	1832
...	...	...	...	...	900	.....	.....	1833
...	...	...	...	...	1298	.....	£20 0 0	1834
...	...	...	...	...	...	.....	167 0 0	1835
...	...	...	...	...	1350	.....	435 0 0	1836
...	...	...	...	...	1840	.....	922 12 6	1837
...	...	...	1100*	...	2400	.....	932 2 2	1838
...	...	...	...	34	1438	.....	1595 11 0	1839
...	...	...	...	40	1353	.....	1546 16 4	1840
46	317	...	60*	...	891	.....	1235 10 11	1841
75	376	33†	331*	28	1315	.....	1449 17 8	1842
71	185	...	160	...	...	.....	1565 10 2	1843
45	190	9†	260	...	...	.....	981 12 8	1844
94	22	407	172	35	1079	.....	831 9 9	1845
65	39	270	196	36	857	.....	685 16 0	1846
197	40	495	203	53	1320	.....	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26&60 H.§	1777	1538 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	35	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	12	2437	2441 0 0	1417 0 11	1889
368	92	680	334	21	1775	1776 0 0	789 16 8	1890
341	152	672	107	12	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892

Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

REPORT OF THE COUNCIL.

Report of the Council for the year 1891–92, *presented to the General Committee at Edinburgh, on Wednesday, August* 3, 1892.

The Council have received reports from the General Treasurer during the past year, and his account from August 1, 1891 to June 30, 1892, which has been audited, will be presented to the General Committee.

An invitation to hold the Annual Meeting of the Association at Oxford in 1894 has been received, and will be brought before the General Committee on Monday.

Resolutions referred to the Council for consideration and action if desirable :—

(A) 'That Mr. C. L. Tupper's paper on "Recent Progress in Indian Agriculture," and Mr. W. C. Furnivall's paper on "Recent Progress in Indian Railways," be printed *in extenso*.'

The Council resolved that Mr. Tupper's paper should be printed in full, and Mr. Furnivall's in abstract.

(B) 'That the General Committee meet on the Monday at 3.30 P.M., and the Committee of Recommendations meet on the Tuesday at 3.30 P.M.'

The Council recommend to the General Committee that their meeting on Monday be held at 3.15 P.M., and that the meeting of the Committee of Recommendations on Tuesday be held at 3.15 P.M.

Resolutions referring to the Ordnance Survey, viz. :—

(C) 1. 'That the publication of the one-inch and six-inch Ordnance Survey Maps is, in the interests of Science, urgently required at the earliest possible date, no less than in the interests of Industry, Manufacture, and Technical Education.'

2. 'That steps be taken and provision made for keeping the Ordnance Maps up to date.'

3. 'That the Maps should be made more accessible to the public, and should be sold at a lower price, as is the case in nearly all other official publications, such as Admiralty Charts, Blue-Books, etc.'

The Council have been informed that the President of the Board of Agriculture has appointed a Departmental Committee to inquire into the state of the Ordnance Survey, and as this Committee has not yet reported, the Council have taken no further action in the matter.

The following Resolutions, which were passed by the Australasian Association for the Advancement of Science at the meeting held at Christchurch, New Zealand, 1891, have been received by the Council :—

RESOLUTIONS.

'(1) That it is desirable to secure greater uniformity in Biological nomenclature, especially in the department of Morphology.

'(2) That in order to secure such uniformity the following steps be taken:—

'(*a*) The appointment of an International Committee to define terms of general importance, *e.g.*, terms common to Botany and Zoology, terms relating to Position, etc.

'(*b*) The preparation of an authoritative historical glossary of Biological terms.

'(*c*) The systematic record of new terms in the various recording publications.

'(3) That copies of these Resolutions be transmitted to the British and American Associations, and to the Anatomische Gesellschaft.'

The Council appointed a Committee consisting of Dr. Sclater, Dr. Woodward, Professor Marshall Ward and Professor Howes to consider these proposals, and have adopted their report in the following terms:—

'After considering the Resolutions submitted by the Australasian Association for the Advancement of Science, we think from the context that by the word "nomenclature" in the first resolution, is meant "terminology." Assuming this to be the case, we quite agree that it would be desirable to secure greater uniformity in Biological terminology, but we doubt whether the appointment of an International Committee would tend to secure that object.

'As regards the recommendation (*b*) in the second Resolution, we also quite agree that the preparation of a good glossary of Biological terms would be of great advantage, if a qualified person could be induced to undertake the task of editorship. We also agree that the glossary ought to be supplemented from time to time by records, to be kept up in the various recording publications.'

This Report will be transmitted to the Australasian Association.

The Report of the Corresponding Societies Committee has been received, and will be presented to the General Committee.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola, Sir Douglas Galton, Sir Rawson Rawson, Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, Mr. W. Topley, Professor T. G. Bonney, and Mr. T. V. Holmes, is hereby nominated for re-appointment by the General Committee, together with Mr. E. B. Poulton, Mr. Cuthbert Peek, and the Rev. Canon Tristram, in the place of Professor A. W. Williamson, Professor Boyd Dawkins, and General Pitt Rivers.

The Council nominate Professor R. Meldola, F.R.S., Chairman, Mr. G. J. Symons, F.R.S., Vice-Chairman, and Mr. T. V. Holmes, F.G.S., Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Edinburgh.

In accordance with the regulations the retiring Members of the Council, exclusive of the late Mr. H. W. Bates, will be:—

Prof. G. H. Darwin.	Prof. J. W. Judd.
Sir J. N. Douglass.	Prof. T. E. Thorpe.

The Council recommend the re-election of the other ordinary Members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Anderson, Dr. W., F.R.S.
Ayrton, Prof. W. E., F.R.S.
Baker, Sir B., K.C.M.G., F.R.S.
*Ball, Sir R. S., F.R.S.
Edgeworth Prof., M.A.
Evans, Sir J., K.C.B., F.R.S.
Fitzgerald, Prof. G. F., F.R.S.
Glazebrook, R. T., Esq., F.R.S.
*Grant-Duff, Sir M. E., G.C.S.I., F.R.S.
*Green, Prof. A. H., F.R.S.
Liveing, Prof. G. D., F.R.S.
Lodge, Prof. Oliver J., F.R.S.
*Meldola, Prof. R., F.R.S.
Preece, W. H., Esq., F.R.S.
Ramsay, Prof. W., F.R.S.
Reinold, Prof. A. W., F.R.S.
Roberts-Austen, Prof. W. C., C.B., F.R.S.
Schäfer, Prof. E. A., F.R.S.
Schuster, Prof. A., F.R.S.
Sidgwick, Prof. H., M.A.
Symons, G. J., Esq., F.R.S.
*Unwin, Prof. W. C., F.R.S.
Ward, Prof. Marshall, F.R.S.
Whitaker, W., Esq., F.R.S.
Woodward, Dr. H., F.R.S.

Committees appointed by the General Committee at the Edinburgh Meeting in August 1892.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants £	s.	d.
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements. [Including an unexpended balance of 10*l*, from last year's grant.]	*Chairman.*—Professor G. Carey Foster. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors Ayrton, J. Perry, W. G. Adams, and O. J. Lodge, Lord Rayleigh, Drs. John Hopkinson and A. Muirhead, Messrs. W. H. Preece and Herbert Taylor, Professors Everett and Schuster, Dr. J. A. Fleming, Professors G. F. Fitzgerald, Chrystal, and J. J. Thomson, Mr. W. N. Shaw, Mr. J. T. Bottomley, and Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, and Professor G. Forbes.	25	0	0
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Mr. John Murray and Dr. A. Buchan, Professor R. Copeland, and Hon. R. Abercromby.	150	0	0
The Application of Photography to the Elucidation of Meteorological Phenomena.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. A. W. Clayden. Professor R. Meldola and Mr. John Hopkinson.	10	0	0
For Calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form. [Last year's grant renewed.]	*Chairman.*—Lord Rayleigh. *Secretary.*—Professor A. Lodge. Lord Kelvin, Professor Cayley, Professor B. Price, Dr. J. W. L. Glaisher, Professor A. G. Greenhill, and Professor W. M. Hicks.	15	0	0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £	s.	d.
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Sir G. G. Stokes. *Secretary.*—Professor H. McLeod. Professor A. Schuster, Mr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain W. de W. Abney, Mr. G. M. Whipple, Mr. G. J. Symons, and Mr. W. E. Wilson.	10	0	0
To co-operate with the Royal Cornwall Polytechnic Society in promoting the Magnetic work of the Falmouth Observatory.	*Chairman.*—Mr. Howard Fox. *Secretary.*—Mr. Howard Fox. Professors A. W. Rücker and W. G. Adams.	25	0	0
Preparing a new Series of Wavelength Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Mr. Lockyer, Professors Dewar, Liveing, Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.	10	0	0
To consider the best Method of establishing an International Standard for the Analysis of Iron and Steel.	*Chairman.* — Professor Roberts-Austen. *Secretary.*—Mr. Thomas Turner. Sir F. Abel, Messrs. E. Riley and J. Spiller, Professor J. W. Langley, Mr. G. J. Snelus, and Professor W. A. Tilden.	20	0	0
The Investigation of the direct Formation of Haloids from pure Materials. [This grant includes 13*l.* 5*s.*, the balance of last year's grant not drawn.]	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr. W. A. Shenstone. Professor W. R. Dunstan and Mr. C. H. Bothamley.	15	0	0
The Action of Light upon Dyed Colours.	*Chairman.*—Professor T. E. Thorpe. *Secretary.*—Professor J. J. Hummel. Dr. Perkin, Professor Russell, Captain Abney, Professor Stroud, and Professor Meldola.	5	0	0
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.	20	0	0
Recording the Position, Height above the Sea, Lithological Characters, Size, and Origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. P. F. Kendall. Professors W. Boyd Dawkins, T. McK. Hughes, T. G. Bonney, and J. Prestwich, Dr. H. W. Crosskey, Messrs. C. E. De Rance, R. H. Tiddeman, J. W. Woodall, and Prof. L. C. Miall.	10	0	0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
The Description and Illustration of the Fossil Phyllopoda of the Palæozoic Rocks.	*Chairman.*—Rev. Prof. T. Wiltshire. *Secretary.*—Professor T. R. Jones. Dr. H. Woodward.	5 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Geological interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Mr. O. W. Jeffs. Professors Bonney and Boyd Dawkins, Drs. V. Ball and T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, W. W. Watts, J. W. Davis, and R. H. Tiddeman.	10 0 0
The Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various Towns and Districts from these Formations. And that a Digest of the eighteen Reports should be prepared by the Committee, and sold in a separate form.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. C. E. De Rance. Dr. H. W. Crosskey, Sir D. Galton, Professor J. Prestwich, and Messrs. J. Glaisher, P. F. Kendall, E. B. Marten, G. H. Morton, W. Pengelly, J. Plant, I. Roberts, T. S. Stooke, G. J. Symons, W. Topley, Tylden-Wright, E. Wethered, and W. Whitaker.	5 0 0
To investigate the character of the high-level shell-bearing deposits at Clava, Chapelhall, and other localities.	*Chairman.*—Mr. J. Horne. *Secretary.*—Mr. Dugald Bell. Messrs. J. Fraser, P. F. Kendall, J. F. Jamieson, and David Robertson.	20 0 0
The Investigation of the Eurypterid-bearing Deposits of the Pentland Hills.	*Chairman.*—Dr. R. H. Traquair. *Secretary.*—Mr. M. Laurie. Professor T. Rupert Jones.	10 0 0
To appoint Mr. Cecil Duncan to investigate the effect of light on Algæ at the Zoological Station at Naples, or, failing this, to appoint some other competent investigator to carry on a definite piece of work at the Zoological Station at Naples approved by the Council.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. Percy Sladen. Professors Ray Lankester, Cossar Ewart, M. Foster, and A. Milnes Marshall and Mr. A. Sedgwick.	100 0 0
To arrange for the Occupation of a Table at the Laboratory of the Marine Biological Association, Plymouth, in order to enable Mr. F. Gamble, B.Sc., to investigate the British Turbellaria.	*Chairman.*—Professor E. Ray Lankester. *Secretary.*—Mr. S. F. Harmer. Professors M. Foster and S. H. Vines.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To report on the present state of our Knowledge of the Zoology of the Sandwich Islands, and to take steps to investigate ascertained deficiencies in the Fauna, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Dr. S. J. Hickson, Professor Riley, Mr. O. Salvin, Dr. P. L. Sclater, and Mr. Edgar A. Smith.	100 0 0
To report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and to take steps to investigate ascertained deficiencies in the Fauna and Flora.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. G. Murray. Mr. W. Carruthers, Drs. A. C. Günther and D. Sharp, Mr. F. Du Cane Godman, Professor A. Newton, and Dr. D. H. Scott.	50 0 0
Exploration of Irish Sea.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. I. C. Thompson. Professor A. C. Haddon, Mr. Hoyle, Mr. A. O. Walker, and Mr. G. Brook.	30 0 0
The Physiological Action of the inhalation of oxygen in asphyxia, more especially in coal-mines.	*Chairman.*—Professor John G. McKendrick, M.D. *Secretary.*—Mr. J. E. F. Thomson, M.B. Mr. J. T. Bottomley.	20 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. G. Brook. Dr. P. L. Sclater, Dr. H. Woodward.	20 0 0
The Exploration of the Glacial Region of the Karakorum Mountains, Physically, Geologically, and Biologically, by Mr. W. M. Conway and companions.	*Chairman.*—Colonel Godwin-Austen. *Secretary.*—Professor T. G. Bonney. Colonel H. C. B. Tanner	50 0 0
Scottish Place-Names.	*Chairman.*—Sir C. W. Wilson. *Secretary.*—Dr. J. Burgess. Mr. Coutts Trotter.	10 0 0
Climatological and Hydrographical Conditions of Tropical Africa.	*Chairman.*—Mr. E. G. Ravenstein. *Secretary.*—Dr. H. R. Mill. Mr. G. J. Symons and Mr. Baldwin Latham.	50 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
The Methods of Economic Training adopted in this and other countries.	*Chairman.*—Professor W. Cunningham. *Secretary.*—Professor E. C. K. Gonner. Professor F. Y. Edgeworth, Professor H. S. Foxwell, Dr. J. N. Keynes, and Mr. H. Higgs.	5 0 0
For carrying on the Work of the Anthropometric Laboratory.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Dr. J. G. Garson. Mr. G. W. Bloxam, Dr. Wilberforce Smith, and Professor A. C. Haddon	5 0 0
Exploration of Ancient Remains at Axume and Adule in Abyssinia.	*Chairman.*—Dr. J. G. Garson. *Secretary.*—Mr. J. Theodore Bent. Mr. F. W. Rudler, Mr. E. W. Brabrook, and Mr. Bloxam.	25 0 0
The Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada.	*Chairman.*—Dr. E. B. Tylor. *Secretary.*—Mr. G. W. Bloxam. Dr. G. M. Dawson, Mr. R. G. Haliburton, and Mr. H. Hale.	100 0 0
The Habits, Customs, Physical Characteristics, and Religions of the Natives of India. [Last year's grant renewed.]	*Chairman.*—Sir William Turner. *Secretary.*—Mr. G. W. Bloxam. Sir W. H. Flower, Drs. Garson and E. B. Tylor, and Mr. H. H. Risley.	10 0 0
Corresponding Societies' Committee.	*Chairman.*—Professor R. Meldola. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Sir Rawson Rawson, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. W. Whitaker, Mr. W. Topley, Mr. E. B. Poulton, Mr. Cuthbert Peek, and Rev. Canon H. B. Tristram.	30 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
To consider the establishment of a National Physical Laboratory for the more accurate determination of Physical Constants, and for other Quantitative Research, and to confer with the Council of the Association.	*Chairman.*—Professor Oliver J. Lodge. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Lord Rayleigh, Sir H. E. Roscoe, Professors J. J. Thomson, Rücker, Clifton, Fitzgerald, Carey Foster, J. Viriamu Jones, A. Schuster, and W. E. Ayrton.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The various Phenomena connected with the recalescent Points in Iron and other Metals.	*Chairman.*—Professor Fitzgerald. *Secretary.*—Professor Barrett. Dr. John Hopkinson, Mr. R. A. Hadfield, Mr. Trouton, Professor Roberts-Austen, and Mr. H. F. Newall.
The Volcanic and Seismological Phenomena of Japan.	*Chairman.*—Lord Kelvin. *Secretary.*—Professor J. Milne. Professor W. G. Adams, Mr. J. T. Bottomley, Professor A. H. Green, and Professor C. G. Knott.
Carrying on the Tables connected with the Pellian Equation from the point where the work was left by Degen in 1817.	*Chairman.*—Professor A. Cayley. *Secretary.*—Professor A. Lodge. Professor Sylvester and Mr. A. R. Forsyth.
To investigate the Phenomena accompanying the Discharge of Electricity from Points.	*Chairman.*—Professor O. J. Lodge. *Secretary.*—Mr. A. P. Chattock. Professor Carey Foster.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Professor W. G. Adams. Lord Kelvin, Professors G. H. Darwin and G. Chrystal, Mr. C. H. Carpmael, Professor Schuster, Mr. G. M. Whipple, Captain Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.
Modes of Measuring the Optical Constants of Microscopic, Photographic, and other Lenses, and of specifying and enumerating the Properties of their Combinations.	*Chairman.*—Professor G. C. Foster. *Secretary.*—Professor S. P. Thompson. Mr. R. T. Glazebrook, Mr. J. Walker, Sir Howard Grubb, Mr. Whipple, and Captain Abney.
To co-operate with Dr. Piazzi Smyth in his Researches on the Ultra Violet Rays of the Solar Spectrum.	*Chairman.*—Professor G. D. Liveing. *Secretary.*—Dr. Piazzi Smyth. Professors J. Dewar and A. Schuster.
The Collection and Identification of Meteoric Dust.	*Chairman.*—Mr. John Murray. *Secretary.*—Mr. John Murray. Professor Schuster, Lord Kelvin, the Abbé Renard, Dr. A. Buchan, the Hon. R. Abercromby, Dr. M. Grabham, and Mr. John Aitken.
The Rate of Increase of Underground Temperature downwards in various Localities of dry Land and under Water.	*Chairman.*—Professor Everett. *Secretary.*—Professor Everett. Professor Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Prestwich, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, and Professor Michie Smith.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To co-operate with Dr. Kerr in his researches on Electro-optics.	*Chairman.*—Dr. John Kerr. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin and Professor A. W. Rücker.
The Properties of Solutions.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professor W. Ramsay.
Reporting on the Bibliography of Solution.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professors McLeod, Pickering, Ramsay, and Young.
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Professor Roberts-Austen. Mr. H. G. Madan and Mr. D. H. Nagel.
The Influence of the Silent Discharge of Electricity on Oxygen and other Gases.	*Chairman.*—Professor H. McLeod. *Secretary.*—Mr. W. A. Shenstone. Professor W. Ramsay and Mr. J. T. Cundall.
The Action of Light on the Hydracids of the Halogens in presence of Oxygen.	*Chairman.*—Dr. W. J. Russell. *Secretary.*—Dr. A. Richardson. Captain Abney and Professors Noel Hartley and W. Ramsay.
To inquire into the Proximate Chemical Constituents of the various kinds of Coal.	*Chairman.*—Sir I. Lowthian Bell. *Secretary.*—Professor P. Phillips Bedson. Mr. Ludwig Mond, Professors Vivian B. Lewes and E. Hull, and Messrs. J. W. Thomas and H. Bauerman.
To report on recent Inquiries into the History of Chemistry.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Professor John Ferguson.
The Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that action.	*Chairman.*—Mr. W. Whitaker. *Secretaries.*—Messrs. C. E. De Rance and W. Topley. Messrs. J. B. Redman and J. W. Woodall, Maj.-Gen. Sir A. Clarke, Admiral Sir E. Ommanney, Capt. Sir G. Nares, Capt. J. Parsons, Capt. W. J. L. Wharton, Professor J. Prestwich, and Messrs. E. Easton and J. S. Valentine, and Professor L. F. Vernon Harcourt.
The Volcanic Phenomena of Vesuvius and its neighbourhood.	*Chairman.*—Mr. H. Bauerman. *Secretary.*—Dr. H. J. Johnston-Lavis. Messrs. F. W. Rudler and J. J. H. Teall.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
Considering the advisability and possibility of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. C. Davison. Sir F. J. Bramwell, Mr. E. A. Cowper, Professor G. H. Darwin, Professor Ewing, Mr. Isaac Roberts, Mr. Thomas Gray, Sir John Evans, Professors Prestwich, Hull, Lebour, Meldola, and Judd, Mr. M. Walton Brown, Mr. J. Glaisher, Professor C. G. Knott, Professor J. H. Poynting, and Mr. Horace Darwin.
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne and Messrs. R. Kidston and J. E. Marr.
To complete the Investigation of the Cave at Elbolton, near Skipton, in order to ascertain whether the remains of Palæolithic Man occur in the Lower Cave Earth.	*Chairman.*—Mr. J. W. Davis. *Secretary.*—Rev. E. Jones. Sir J. Evans, Dr. J. G. Garson, and Messrs. W. Pengelly, R. H. Tiddeman, and J. J. Wilkinson.
To carry on Excavations at Oldbury Hill, near Ightham, in order to ascertain the existence or otherwise of Rock Shelters at that spot.	*Chairman.*—Sir J. Evans. *Secretary.*—Mr. B. Harrison. Professors Prestwich and H. G. Seeley.
To consider a project for investigating the Structure of a Coral Reef by Boring and Sounding.	*Chairman.*—Professor T. G. Bonney. *Secretary.*—Professor W. J. Sollas. Sir Archibald Geikie, Professors A. H. Green, J. W. Judd, C. Lapworth, A. C. Haddon, Boyd Dawkins, G. H. Darwin and A. Stewart, Captain Wharton, Drs. H. Hicks, J. Murray, and H. B. Guppy, Messrs. F. Darwin, H. O. Forbes, G. C. Bourne, S. Hickson, A. R. Binnie, and J. W. Gregory, and Hon. P. Fawcett.
For improving and experimenting with a Deep-sea Tow-net for opening and closing under water.	*Chairman.*—Professor A. C. Haddon. *Secretary.*—Mr. W. E. Hoyle. Professor W. A. Herdman.
To make a Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels.	*Chairman.*—Professor A. Newton. *Secretary.*—Mr. John Cordeaux. Messrs. John A. Harvie-Brown, R. M. Barrington, and W. E. Clarke and the Rev. E. P. Knubley.
For taking steps to establish a Botanical Laboratory at Peradeniya, Ceylon.	*Chairman.*—Professor M. Foster. *Secretary.*—Professor J. B. Farmer. Professor Bayley Balfour, Mr. Thiselton-Dyer, Dr. Trimen, Professor Marshall Ward, Mr. Carruthers, Professor Hartog, Professor F. O. Bower, and Mr. W. Gardiner.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To consider proposals for the Legislative Protection of Wild Birds' Eggs.	*Chairman.*—Mr. Thomas Henry Thomas. *Secretary.*—Dr. C. T. Vachell. Professors W. N. Parker, Newton, and Leipner, Mr. Poulton, and Canon Tristram.
The Teaching of Science in Elementary Schools	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Mr. S. Bourne, Dr. Crosskey, Mr. George Gladstone, Mr. J. Heywood, Sir J. Lubbock, Sir Philip Magnus, Professor N. Story Maskelyne, Sir H. E. Roscoe, Sir R. Temple, and Professor Silvanus P. Thompson.
To report on Methods of determining the dryness of Steam in boiler trials.	*Chairman.*—Sir F. J. Bramwell. *Secretary.*—Professor W. C. Unwin. Professor A. B. W. Kennedy, Mr. Mair Rumley, Mr. Jeremiah Head, and Professor Osborne Reynolds.
To draw up a Third Report on the Development of Graphic Methods in Mechanical Science.	*Chairman.*—Mr. W. H. Preece. *Secretary.*—Professor H. S. Hele Shaw. Lord Kelvin and Sir Benjamin Baker.
To organise an Ethnographical Survey of the United Kingdom.	*Chairman.*—Mr. Francis Galton. *Secretary.*—Mr. E. W. Brabrook. Dr. J. G. Garson, Professor A. C. Haddon, and Dr. Joseph Anderson.
The Prehistoric and Ancient Remains of Glamorganshire.	*Chairman.*—Dr. C. T. Vachell. *Secretary.*—Mr. E. Seward. Lord Bute, Messrs. G. T. Clark, R. W. Atkinson, Franklen G. Evans, James Bell, and T. H. Thomas, and Dr. J. G. Garson.
Ascertaining and recording the Localities in the British Islands in which evidence of the existence of Prehistoric Inhabitants of the Country are found.	*Chairman.*—Sir John Lubbock. *Secretary.*—Mr. J. W. Davis. Sir John Evans, Professor Boyd Dawkins, Dr. R. Munro, Mr. Pengelly, Dr. Hicks, and Professor R. Meldola.
To consider Uniformity in the Spelling of Barbaric and Savage Languages and Race Names.	*Chairman.*—Mr. F. Galton. *Secretary.*—Mr. C. E. Peek. Dr. E. B. Tylor, Professor A. C. Haddon, Mr. G. W. Bloxam, and Mr. Ling Roth.
To investigate the Physical Deviations from the Normal among Children in Elementary and other Schools.	*Chairman.*—Sir Douglas Galton. *Secretary.*—Dr. Francis Warner. Mr. G. W. Bloxam, Mr. E. W. Brabrook, and Dr. J. G. Garson.

Other Resolutions adopted by the General Committee.

That Mr. W. N. Shaw be requested to continue his Report on the present state of our Knowledge in Electrolysis and Electro-chemistry.

That Dr. J. Larmor and Mr. G. H. Bryan be requested to continue their Report on the present state of our Knowledge in Thermodynamics, specially with regard to the Second Law.

That Professor A. Michelson's paper on 'The Application of Interference-Methods to Spectroscopic Measurement' be printed *in extenso* in the Report of the Association.

That M. Guillaume's paper on 'Physical Constants and Units' be printed *in extenso* among the Reports.

That the Report drawn up by Professor H. S. Hele Shaw on 'Graphic Methods' be printed *in extenso*, with the necessary drawings, among the Reports.

That the paper by Mr. G. F. Deacon on 'Shield Tunnelling in Loose Ground under Water Pressure' be printed *in extenso* with the necessary diagrams.

That the Organising Committee of a Section be empowered to arrange the hours of meeting of the Section and the Sectional Committee.

Resolutions, &c., referred to the Council for consideration, and action if desirable.

That the Council be requested to draw the attention of the Local Government Board to the desirability of the publication of the Report on the Examination into Deviations from the Normal amongst 50,000 Children in various Schools, which has been presented to that Board by the British Medical Association.

That the Council be requested to draw the attention of Her Majesty's Government to the Anthropometric Method for the measurement of criminals, which is successfully in operation in France, Austria, and other continental countries, and which has been found effective in the identification of habitual criminals, and consequently in the prevention and repression of crime.

The letter of Professor E. Wiedemann and the communications from the Committees of Sections B and C on the subject of the Headings of Reports.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Edinburgh Meeting, in August 1892. *The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

	£	s.	d.
*Foster, Professor Carey—Electrical Standards (partly renewed)	25	0	0
*McLaren, Lord.—Meteorological Observations on Ben Nevis	150	0	0
*Symons, Mr. G. J.—Photographs of Meteorological Phenomena	10	0	0
*Rayleigh, Lord—Tables of Mathematical Functions	15	0	0
*Stokes, Sir G. G.—Recording the Direct Intensity of Solar Radiation	10	0	0
Fox, Mr. H.—Magnetic Work at the Falmouth Observatory	25	0	0

Chemistry and Mineralogy.

*Roscoe, Sir H.—Wave-length Tables of the Spectra of the Elements	10	0	0
*Roberts-Austen, Professor—Analysis of Iron and Steel	20	0	0
*Armstrong, Professor H. E.—Formation of Haloids from Pure Materials (partly renewed)	15	0	0
*Thorpe, Professor T. E.—Action of Light upon Dyed Colours	5	0	0
*Tilden, Professor W. A.—Isomeric Naphthalene Derivatives	20	0	0

Geology.

*Prestwich, Professor J.—Erratic Blocks	10	0	0
*Wiltshire, Rev. T.—Fossil Phyllopoda	5	0	0
*Geikie, Professor J.—Photographs of Geological Interest	10	0	0
*Hull, Professor E.—Underground Waters	5	0	0
*Horne, Mr. J.—Shell-bearing deposits at Clava, Chapelhall, &c.	20	0	0
Traquair, Dr. R. H.—Eurypterids of the Pentland Hills	10	0	0
Carried forward	£365	0	0

* Reappointed.

	£	s.	d.
Brought forward	365	0	0
Biology.			
*Sclater, Dr. P. L.—Table at the Naples Zoological Station	100	0	0
*Lankester, Professor E. R.—Table at the Plymouth Biological Laboratory	30	0	0
*Newton, Professor A.—Fauna of Sandwich Islands	100	0	0
*Sclater, Dr. P. L.—Zoology and Botany of West India Islands	50	0	0
Herdman, Professor W. A.—Exploration of Irish Sea	30	0	0
M'Kendrick, Professor J. G.—Physiological Action of Oxygen in Asphyxia	20	0	0
Flower, Sir W. H.—Index of Genera and Species of Animals	20	0	0
Geography.			
Godwin-Austen, Col.—Exploration of Karakorum Mountains	50	0	0
Wilson, Sir C. W.—Scottish Place Names	10	0	0
*Ravenstein, Mr. E. G.—Climatology and Hydrography of Tropical Africa	50	0	0
Economic Science and Statistics.			
Cunningham, Professor W.—Methods of Economic Training	5	0	0
Anthropology.			
*Flower, Sir W. H.—Anthropometric Laboratory	5	0	0
Garson, Dr. J. G.—Exploration of Ancient Remains in Abyssinia	25	0	0
*Tylor, Dr. E. B.—North-Western Tribes of Canada	100	0	0
*Turner, Sir W.—Habits, Customs, &c., of Natives of India (renewed)	10	0	0
Corresponding Societies.			
*Meldola, Professor R.—Corresponding Societies' Committee	30	0	0
	£1,000	0	0

* Reappointed.

The Annual Meeting in 1893.

The Meeting at Nottingham will commence on Wednesday, September 13.

Place of Meeting in 1894.

The Annual Meeting of the Association will be held at Oxford.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-iron Experiments	103	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

	£	s.	d.
1844.			
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology....1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

	£	s.	d.
1845.			
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

	£	s.	d.
1846.			
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	5	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

	£	s.	d.
1847.			
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

	£	s.	d.
1848.			
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8
1849.			
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6
1850.			
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

	£	s.	d.
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854.....£ 75 0 0 1855.....£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860.....£50 0 0 / 1861.....£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid.....	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland.....	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record.....	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

Printing Mathematical Tables	159	4	2
British Rainfall.....	100	0	0
Ohm's Law.....	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate.....	5	0	0
Estimation of Potash and Phosphoric Acid.....	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record.....	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland.....	1	10	0
Zoological Record.....	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station.....	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles.....	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

Liquid Carbonic Acids in Minerals.....	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record.....	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on.....	20	0	0
Mechanical Equivalent of Heat.....	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid.....	1	18	0
Geological Record.....	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.....	15	0	0
	£1128	9	7

1878.

Exploration of Settle Caves	100	0	0
Geological Record.....	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters.....	15	0	0
Transmission of Electrical Impulses through Nerve Structure.....	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less-known Alkaloids.....	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record.....	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors.....	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station	50	0	0
Naples Zoological Station	75	0	0
Natural History of Socotra	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe	25	0	0
Circulation of Underground Waters	15	0	0

	£	s.	d.
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra-Violet Spark Spectra	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Marine Biological Station at Granton	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

	£	s.	d.
1886.			
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Meteorological Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Exploration of Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Zoological Literature Record	100	0	0
Marine Biological Station at Granton	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

	£	s.	d.
1887.			
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Exploration of Cae Gwyn Cave, North Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Circulation of Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museum Reports	5	0	0
Investigation of Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

	£	s.	d.
1888.			
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Circulation of Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0

	£	s.	d.
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

Ben Nevis Observatory	50	0	0
Electrical Standards	75	0	0
Electrolysis	20	0	0
Observations on Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Fossil Phyllopoda of Palæozoic Rocks	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations	100	0	0
Flora of China	25	0	0
Naples Zoological Station	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries by means of Working Models	100	0	0
North-Western Tribes of Canada	150	0	0
Characteristics of Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
Bath 'Baths Committee' for further Researches	100	0	0
	£1417	0	11

1890.

Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Calculating Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Fossil Phyllopoda of the Palæozoic Rocks	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northamptonshire	25	0	0
Botanical Station at Peradeniya	25	0	0
Experiments with a Tow-net	4	3	9
Naples Zoological Station	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Variations of Temperature in Lakes	20	0	0

	£	s.	d.
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias Beds of Northamptonshire	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-Net	40	0	0
Marine Biological Association at Plymouth	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Table at Naples Zoological Station	100	0	0
Table at Plymouth Biological Laboratory	17	10	0
Improving a Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

General Meetings.

On Wednesday, August 3, at 8 P.M., in the Synod Hall, Dr. W. Huggins, F.R.S., Hon. F.R.S.E., F.R.A.S., resigned the office of President to Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., F.G.S., who took the Chair, and delivered an Address, for which see page 3.

On Thursday, August 4, at 8 P.M., a Soirée took place at the Museum of Science and Art.

On Friday, August 5, at 8.30 P.M., in the Synod Hall, Professor A. Milnes Marshall, M.A., M.D., F.R.S , delivered a discourse on 'Pedigrees.'

On Monday, August 8, at 8.30 P.M., in the Synod Hall, Professor J. A. Ewing, M.A., F.R.S., delivered a discourse on 'Magnetic Induction.'

On Tuesday, August 9, at 8 P.M., a Soirée took place at the Music Hall.

On Wednesday, August 10, at 2.30 P.M., in the Upper Library Hall, University (Old Buildings), the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Nottingham. [The Meeting is appointed to commence on Wednesday, September 13, 1893.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

SIR ARCHIBALD GEIKIE,

LL.D., D.Sc, For.Sec.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom,

PRESIDENT.

In its beneficent progress through these islands the British Association for the Advancement of Science now for the fourth time receives a welcome in this ancient capital. Once again, under the shadow of these antique towers, crowded memories of a romantic past fill our thoughts. The stormy annals of Scotland seem to move in procession before our eyes as we walk these streets, whose names and traditions have been made familiar to the civilised world by the genius of literature. At every turn, too, we are reminded, by the monuments which a grateful city has erected, that for many generations the pursuits which we are now assembled to foster have had here their congenial home. Literature, philosophy, science, have each in turn been guided by the influence of the great masters who have lived here, and whose renown is the brightest gem in the chaplet around the brow of this 'Queen of the North.'

Lingering for a moment over these local associations, we shall find a peculiar appropriateness in the time of this renewed visit of the Association to Edinburgh. A hundred years ago a remarkable group of men was discussing here the great problem of the history of the earth. James Hutton, after many years of travel and reflection, had communi-

cated to the Royal Society of this city, in the year 1785, the first outlines of his famous 'Theory of the Earth.' Among those with whom he took counsel in the elaboration of his doctrines were Black, the illustrious discoverer of 'fixed air' and 'latent heat'; Clerk, the sagacious inventor of the system of breaking the enemy's line in naval tactics; Hall, whose fertile ingenuity devised the first system of experiments in illustration of the structure and origin of rocks; and Playfair, through whose sympathetic enthusiasm and literary skill Hutton's views came ultimately to be understood and appreciated by the world at large. With these friends, so well able to comprehend and criticise his efforts to pierce the veil that shrouded the history of this globe, he paced the streets amid which we are now gathered together; with them he sought the crags and ravines around us, wherein Nature has laid open so many impressive records of her past; with them he sallied forth on those memorable expeditions to distant parts of Scotland, whence he returned laden with treasures from a field of observation which, though now so familiar, was then almost untrodden. The centenary of Hutton's 'Theory of the Earth' is an event in the annals of science which seems most fittingly celebrated by a meeting of the British Association in Edinburgh.

In choosing from among the many subjects which might properly engage your attention on the present occasion, I have thought that it would not be inappropriate nor uninteresting to consider the more salient features of that 'Theory,' and to mark how much in certain departments of inquiry has sprung from the fruitful teaching of its author and his associates.

It was a fundamental doctrine of Hutton and his school that this globe has not always worn the aspect which it bears at present; that, on the contrary, proofs may everywhere be culled that the land which we now see has been formed out of the wreck of an older land. Among these proofs, the most obvious are supplied by some of the more familiar kinds of rock, which teach us that, though they are now portions of the dry land, they were originally sheets of gravel, sand, and mud, which had been worn from the face of long-vanished continents, and after being spread out over the floor of the sea were consolidated into compact stone, and were finally broken up and raised once more to form part of the dry land. This cycle of change involved two great systems of natural processes. On the one hand, men were taught that by the action of running water the materials of the solid land are in a state of continual decay and transport to the ocean. On the other hand, the ocean-floor is

liable from time to time to be upheaved by some stupendous internal force akin to that which gives rise to the volcano and the earthquake. Hutton further perceived that not only had the consolidated materials been disrupted and elevated, but that masses of molten rock had been thrust upward among them, and had cooled and crystallised in large bodies of granite and other eruptive rocks which form so prominent a feature on the earth's surface.

It was a special characteristic of this philosophical system that it sought in the changes now in progress on the earth's surface an explanation of those which occurred in older times. Its founder refused to invent causes or modes of operation, for those with which he was familiar seemed to him adequate to solve the problems with which he attempted to deal. Nowhere was the profoundness of his insight more astonishing than in the clear, definite way in which he proclaimed and reiterated his doctrine, that every part of the surface of the continents, from mountain-top to sea-shore, is continually undergoing decay, and is thus slowly travelling to the sea. He saw that no sooner will the sea-floor be elevated into new land than it must necessarily become a prey to this universal and unceasing degradation. He perceived that, as the transport of disintegrated material is carried on chiefly by running water, rivers must slowly dig out for themselves the channels in which they flow, and thus that a system of valleys, radiating from the water-parting of a country, must necessarily result from the descent of the streams from the mountain crests to the sea. He discerned that this ceaseless and wide-spread decay would eventually lead to the entire demolition of the dry land, but he contended that from time to time this catastrophe is prevented by the operation of the underground forces, whereby new continents are upheaved from the bed of the ocean. And thus in his system a due proportion is maintained between land and water, and the condition of the earth as a habitable globe is preserved.

A theory of the earth so simple in outline, so bold in conception, so full of suggestion, and resting on so broad a base of observation and reflection, ought, we might think, to have commanded at once the attention of men of science, even if it did not immediately awaken the interest of the outside world; but, as Playfair sorrowfully admitted, it attracted notice only very slowly, and several years elapsed before anyone showed himself publicly concerned about it, either as an enemy or a friend. Some of its earliest critics assailed it for what they asserted to be its irreligious tendency—an accusation which Hutton repudiated with much warmth. The sneer levelled by Cowper a few years earlier at all inquiries

into the history of the universe was perfectly natural and intelligible from that poet's point of view. There was then a widespread belief that this world came into existence some six thousand years ago, and that any attempt greatly to increase that antiquity was meant as a blow to the authority of Holy Writ. So far, however, from aiming at the overthrow of orthodox beliefs, Hutton evidently regarded his 'Theory' as an important contribution in aid of natural religion. He dwelt with unfeigned pleasure on the multitude of proofs which he was able to accumulate of an orderly design in the operations of nature, decay and renovation being so nicely balanced as to maintain the habitable condition of the planet. But as he refused to admit the predominance of violent action in terrestrial changes, and on the contrary contended for the efficacy of the quiet, continuous processes which we can even now see at work around us, he was constrained to require an unlimited duration of past time for the production of those revolutions of which he perceived such clear and abundant proofs in the crust of the earth. The general public, however, failed to comprehend that the doctrine of the high antiquity of the globe was not inconsistent with the comparatively recent appearance of man—a distinction which seems so obvious now.

Hutton died in 1797, beloved and regretted by the circle of friends who had learnt to appreciate his estimable character and to admire his genius, but with little recognition from the world at large. Men knew not then that a great master had passed away from their midst, who had laid broad and deep the foundations of a new science; that his name would become a household word in after generations, and that pilgrims would come from distant lands to visit the scenes from which he drew his inspiration.

Many years might have elapsed before Hutton's teaching met with wide acceptance, had its recognition depended solely on the writings of the philosopher himself. For, despite his firm grasp of general principles and his mastery of the minutest details, he had acquired a literary style which, it must be admitted, was singularly unattractive. Fortunately for his fame, as well as for the cause of science, his devoted friend and disciple, Playfair, at once set himself to draw up an exposition of Hutton's views. After five years of labour on this task there appeared the classic 'Illustrations of the Huttonian Theory,' a work which for luminous treatment and graceful diction stands still without a rival in English geological literature. Though professing merely to set forth his friend's doctrines, Playfair's treatise was in many respects an original contribution to science of the highest value. It placed for the first time in the

clearest light the whole philosophy of Hutton regarding the history of the earth, and enforced it with a wealth of reasoning and copiousness of illustration which obtained for it a wide appreciation. From long converse with Hutton, and from profound reflection himself, Playfair gained such a comprehension of the whole subject that, discarding the non-essential parts of his master's teaching, he was able to give so lucid and accurate an exposition of the general scheme of Nature's operations on the surface of the globe, that with only slight corrections and expansions his treatise may serve as a text-book to-day. In some respects, indeed, his volume was long in advance of its time. Only, for example, within the present generation has the truth of his teaching in regard to the origin of valleys been generally admitted.

Various causes contributed to retard the progress of the Huttonian doctrines. Especially potent was the influence of the teaching of Werner, who, though he perceived that a definite order of sequence could be recognised among the materials of the earth's crust, had formed singularly narrow conceptions of the great processes whereby that crust has been built up. His enthusiasm, however, fired his disciples with the zeal of proselytes, and they spread themselves over Europe to preach everywhere the artificial system which they had learnt in Saxony. By a curious fate Edinburgh became one of the great headquarters of Wernerism. The friends and followers of Hutton found themselves attacked in their own city by zealots who, proud of superior mineralogical acquirements, turned their most cherished ideas upside down and assailed them in the uncouth jargon of Freiberg. Inasmuch as subterranean heat had been invoked by Hutton as a force largely instrumental in consolidating and upheaving the ancient sediments that now form so great a part of the dry land, his followers were nicknamed Plutonists. On the other hand, as the agency of water was almost alone admitted by Werner, who believed the rocks of the earth's crust to have been chiefly chemical precipitates from a primeval universal ocean, those who adopted his views received the equally descriptive name of Neptunists. The battle of these two contending schools raged fiercely here for some years, and though mainly from the youth, zeal, and energy of Jameson, and the influence which his position as Professor in the University gave him, the Wernerian doctrines continued to hold their place, they were eventually abandoned even by Jameson himself, and the debt due to the memory of Hutton and Playfair was tardily acknowledged.

The pursuits and the quarrels of philosophers have from early times been a favourite subject of merriment to the outside world. Such a feud

as that between the Plutonists and Neptunists would be sure to furnish abundant matter for the gratification of this propensity. Turning over the pages of Kay's 'Portraits,' where so much that was distinctive of Edinburgh society a hundred years ago is embalmed, we find Hutton's personal peculiarities and pursuits touched off in good-humoured caricature. In one plate he stands with arms folded and hammer in hand, meditating on the face of a cliff, from which rocky prominences in shape of human faces, perhaps grotesque likenesses of his scientific opponents, grin at him. In another engraving he sits in conclave with his friend Black, possibly arranging for that famous banquet of garden-snails which the two worthies had persuaded themselves to look upon as a strangely neglected form of human food. More than a generation later, when the Huttonists and Wernerists were at the height of their antagonism, the humorous side of the controversy did not escape the notice of the author of 'Waverley,' who, you will remember, when he makes Meg Dods recount the various kinds of wise folk brought by Lady Penelope Penfeather from Edinburgh to St. Ronan's Well, does not forget to include those who 'rin uphill and down dale, knapping the chucky-stanes to pieces wi' hammers, like sae mony road-makers run daft, to see how the warld was made.'

Among the names of the friends and followers of Hutton there is one which on this occasion deserves to be held in especial honour, that of Sir James Hall, of Dunglass. Having accompanied Hutton in some of his excursions, and having discussed with him the problems presented by the rocks of Scotland, Hall was familiar with the views of his master, and was able to supply him with fresh illustrations of them from different parts of the country. Gifted with remarkable originality and ingenuity, he soon perceived that some of the questions involved in the theory of the earth could probably be solved by direct physical experiment. Hutton, however, mistrusted any attempt 'to judge of the great operations of Nature by merely kindling a fire and looking into the bottom of a little crucible.' Out of deference to this prejudice Hall delayed to carry out his intention during Hutton's lifetime. But afterwards he instituted a remarkable series of researches which are memorable in the history of science as the first methodical endeavour to test the value of geological speculation by an appeal to actual experiment. The Neptunists, in ridiculing the Huttonian doctrine that basalt and similar rocks had once been molten, asserted that, had such been their origin, these masses would now be found in the condition of glass or slag. Hall, however, triumphantly vindicated his friend's view by proving that basalt could be fused,

and thereafter by slow cooling could be made to resume a stony texture. Again, Hutton had asserted that under the vast pressures which must be effective deep within the earth's crust, chemical reactions must be powerfully influenced, and that under such conditions even limestone may conceivably be melted without losing its carbonic acid. Various specious arguments had been adduced against this proposition, but by an ingeniously devised series of experiments Hall succeeded in converting limestone under great pressure into a kind of marble, and even fused it, and found that it then acted vigorously on other rocks. These admirable researches, which laid the foundations of experimental geology, constitute not the least memorable of the services rendered by the Huttonian school to the progress of science.

Clear as was the insight and sagacious the inferences of these great masters in regard to the history of the globe, their vision was necessarily limited by the comparatively narrow range of ascertained fact which up to their time had been established. They taught men to recognise that the present world is built of the ruins of an earlier one, and they explained with admirable perspicacity the operation of the processes whereby the degradation and renovation of land are brought about. But they never dreamed that a long and orderly series of such successive destructions and renewals had taken place, and had left their records in the crust of the earth. They never imagined that from these records it would be possible to establish a determinate chronology that could be read everywhere, and applied to the elucidation of the remotest quarter of the globe. It was by the memorable observations and generalisations of William Smith that this vast extension of our knowledge of the past history of the earth became possible. While the Scottish philosophers were building up their theory here, Smith was quietly ascertaining by extended journeys that the stratified rocks of the West of England occur in a definite sequence, and that each well-marked group of them can be discriminated from the others and identified across the country by means of its enclosed organic remains. It is nearly a hundred years since he made known his views, so that by a curious coincidence we may fitly celebrate on this occasion the centenary of William Smith as well as that of James Hutton. No single discovery has ever had a more momentous and far-reaching influence on the progress of a science than that law of organic succession which Smith established. At first it served merely to determine the order of the stratified rocks of England. But it soon proved to possess a world-wide value, for it was found to furnish the key to the structure of the whole stratified crust of the earth. It showed that

within that crust lie the chronicles of a long history of plant and animal life upon this planet, it supplied the means of arranging the materials for this history in true chronological sequence, and it thus opened out a magnificent vista through a vast series of ages, each marked by its own distinctive types of organic life, which, in proportion to their antiquity, departed more and more from the aspect of the living world.

Thus a hundred years ago, by the brilliant theory of Hutton and the fruitful generalisation of Smith, the study of the earth received in our country the impetus which has given birth to the modern science of geology.

To review the marvellous progress which this science has made during the first century of its existence would require not one but many hours for adequate treatment. The march of discovery has advanced along a multitude of different paths, and the domains of Nature which have been included within the growing territories of human knowledge have been many and ample. Nevertheless, there are certain departments of investigation to which we may profitably restrict our attention on the present occasion, and wherein we may see how the leading principles that were proclaimed in this city a hundred years ago have germinated and borne fruit all over the world.

From the earliest times the natural features of the earth's surface have arrested the attention of mankind. The rugged mountain, the cleft ravine, the scarped cliff, the solitary boulder, have stimulated curiosity and prompted many a speculation as to their origin. The shells embedded by millions in the solid rocks of hills far removed from the sea have still further pressed home these 'obstinate questionings.' But for many long centuries the advance of inquiry into such matters was arrested by the paramount influence of orthodox theology. It was not merely that the Church opposed itself to the simple and obvious interpretation of these natural phenomena. So implicit had faith become in the accepted views of the earth's age and of the history of creation, that even laymen of intelligence and learning set themselves unbidden and in perfect good faith to explain away the difficulties which Nature so persistently raised up, and to reconcile her teachings with those of the theologians. In the various theories thus originating, the amount of knowledge of natural law usually stood in inverse ratio to the share played in them by an uncontrolled imagination. The speculations, for example, of Burnet, Whiston, Whitehurst, and others in this country, cannot be read now without a smile. In no sense were they scientific researches; they can only be looked upon as exercitations of learned ignorance. Springing

mainly out of a laudable desire to promote what was believed to be the cause of true religion, they helped to retard inquiry, and exercised in that respect a baneful influence on intellectual progress.

It is the special glory of the Edinburgh school of geology to have cast aside all this fanciful trifling. Hutton boldly proclaimed that it was no part of his philosophy to account for the beginning of things. His concern lay only with the evidence furnished by the earth itself as to its origin. With the intuition of true genius he early perceived that the only solid basis from which to explore what has taken place in bygone time is a knowledge of what is taking place to-day. He thus founded his system upon a careful study of the processes whereby geological changes are now brought about. He felt assured that Nature must be consistent and uniform in her working, and that only in proportion as her operations at the present time are watched and understood will the ancient history of the earth become intelligible. Thus, in his hands, the investigation of the Present became the key to the interpretation of the Past. The establishment of this great truth was the first step towards the inauguration of a true science of the earth. The doctrine of uniformity of causation in Nature became the fruitful principle on which the structure of modern geology could be built up.

Fresh life was now breathed into the study of the earth. A new spirit seemed to animate the advance along every pathway of inquiry. Facts that had long been familiar came to possess a wider and deeper meaning when their connection with each other was recognised as parts of one great harmonious system of continuous change. In no department of Nature, for example, was this broader vision more remarkably displayed than in that wherein the circulation of water between land and sea plays the most conspicuous part. From the earliest times men had watched the coming of clouds, the fall of rain, the flow of rivers, and had recognised that on this nicely adjusted machinery the beauty and fertility of the land depend. But they now learnt that this beauty and fertility involve a continual decay of the terrestrial surface; that the soil is a measure of this decay, and would cease to afford us maintenance were it not continually removed and renewed; that through the ceaseless transport of soil by rivers to the sea the face of the land is slowly lowered in level and carved into mountain and valley, and that the materials thus borne outwards to the floor of the ocean are not lost but accumulate there to form rocks, which in the end will be upraised into new lands. Decay and renovation, in well-balanced proportions, were thus shown to be the system on which the existence of the earth as a habitable globe had been

established. It was impossible to conceive that the economy of the planet could be maintained on any other basis. Without the circulation of water the life of plants and animals would be impossible, and with that circulation the decay of the surface of the land and the renovation of its disintegrated materials are necessarily involved.

As it is now so must it have been in past time. Hutton and Playfair pointed to the stratified rocks of the earth's crust as demonstrations that the same processes which are at work to-day have been in operation from a remote antiquity. By thus placing their theory on a basis of actual observation, and providing in the study of existing operations a guide to the interpretation of those in past times, they rescued the investigation of the history of the earth from the speculations of theologians and cosmologists, and established a place for it among the recognised inductive sciences. To the guiding influence of their philosophical system the prodigious strides made by modern geology are in large measure to be attributed. And here in their own city, after the lapse of a hundred years, let us offer to their memory the grateful homage of all who have profited by their labours.

But while we recognise with admiration the far-reaching influence of the doctrine of uniformity of causation in the investigation of the history of the earth, we must upon reflection admit that the doctrine has been pushed to an extreme perhaps not contemplated by its original founders. To take the existing conditions of Nature as a platform of actual knowledge from which to start in an inquiry into former conditions was logical and prudent. Obviously, however, human experience, in the few centuries during which attention has been turned to such subjects, has been too brief to warrant any dogmatic assumption that the various natural processes must have been carried on in the past with the same energy and at the same rate as they are carried on now. Variations in energy might have been legitimately conceded as possible, though not to be allowed without reasonable proof in their favour. It was right to refuse to admit the operation of speculative causes of change when the phenomena were capable of natural and adequate explanation by reference to causes that can be watched and investigated. But it was an error to take for granted that no other kind of process or influence, nor any variation in the rate of activity save those of which man has had actual cognisance, has played a part in the terrestrial economy. The uniformitarian writers laid themselves open to the charge of maintaining a kind of perpetual motion in the machinery of Nature. They could find in the records of the earth's history no evidence of a beginning, no prospect of an end. They

saw that many successive renovations and destructions had been effected on the earth's surface, and that this long line of vicissitudes formed a series of which the earliest were lost in antiquity, while the latest were still in progress towards an apparently illimitable future.

The discoveries of William Smith, had they been adequately understood, would have been seen to offer a corrective to this rigidly uniformitarian conception, for they revealed that the crust of the earth contains the long record of an unmistakable order of progression in organic types. They proved that plants and animals have varied widely in successive periods of the earth's history, the present condition of organic life being only the latest phase of a long preceding series, each stage of which recedes further from the existing aspect of things as we trace it backward into the past. And though no relic had yet been found, or indeed was ever likely to be found, of the first living things that appeared upon the earth's surface, the manifest simplification of types in the older formations pointed irresistibly to some beginning from which the long procession had taken its start. If then it could thus be demonstrated that there had been upon the globe an orderly march of living forms from the lowliest grades in early times to man himself to-day, and thus that in one department of her domain, extending through the greater portion of the records of the earth's history, Nature had not been uniform but had followed a vast and noble plan of evolution, surely it might have been expected that those who discovered and made known this plan would seek to ascertain whether some analogous physical progression from a definite beginning might not be discernible in the framework of the globe itself.

But the early masters of the science laboured under two great disadvantages. In the first place, they found the oldest records of the earth's history so broken up and effaced as to be no longer legible. And in the second place, they lived under the spell of that strong reaction against speculation which followed the bitter controversy between the Neptunists and Plutonists in the earlier decades of the century. They considered themselves bound to search for facts, not to build up theories; and as in the crust of the earth they could find no facts which threw any light upon the primeval constitution and subsequent development of our planet, they shut their ears to any theoretical interpretations that might be offered from other departments of science. It was enough for them to maintain, as Hutton had done, that in the visible structure of the earth itself no trace can be found of the beginning of things, and that the oldest terrestrial records reveal no physical conditions essentially different from

those in which we still live. They doubtless listened with interest to the speculations of Kant, Laplace, and Herschel, on the probable evolution of nebulæ, suns, and planets, but it was with the languid interest attaching to ideas that lay outside of their own domain of research. They recognised no practical connection between such speculations and the data furnished by the earth itself as to its own history and progress.

This curious lethargy with respect to theory on the part of men who were popularly regarded as among the most speculative followers of science would probably not have been speedily dispelled by any discovery made within their own field of observation. Even now, after many years of the most diligent research, the first chapters of our planet's history remain undiscovered or undecipherable. On the great terrestrial palimpsest the earliest inscriptions seem to have been hopelessly effaced by those of later ages. But the question of the primeval condition and subsequent history of the planet might be considered from the side of astronomy and physics. And it was by investigations of this nature that the geological torpor was eventually dissipated. To our illustrious former President, Lord Kelvin, who occupied this chair when the Association last met in Edinburgh, is mainly due the rousing of attention to this subject. By the most convincing arguments he showed how impossible it was to believe in the extreme doctrine of uniformitarianism. And though, owing to uncertainty in regard to some of the data, wide limits of time were postulated by him, he insisted that within these limits the whole evolution of the earth and its inhabitants must have been comprised. While, therefore, the geological doctrine that the present order of Nature must be our guide to the interpretation of the past remained as true and fruitful as ever, it had now to be widened by the reception of evidence furnished by a study of the earth as a planetary body. The secular loss of heat, which demonstrably takes place both from the earth and the sun, made it quite certain that the present could not have been the original condition of the system. This diminution of temperature with all its consequences is not a mere matter of speculation, but a physical fact of the present time as much as any of the familiar physical agencies that affect the surface of the globe. It points with unmistakable directness to that beginning of things of which Hutton and his followers could find no sign.

Another modification or enlargement of the uniformitarian doctrine was brought about by continued investigation of the terrestrial crust and consequent increase of knowledge respecting the history of the earth.

Though Hutton and Playfair believed in periodical catastrophes, and indeed required these to recur in order to renew and preserve the habitable condition of our planet, their successors gradually came to view with repugnance any appeal to abnormal, and especially to violent manifestations of terrestrial vigour, and even persuaded themselves that such slow and comparatively feeble action as had been witnessed by man could alone be recognised in the evidence from which geological history must be compiled. Well do I remember in my own boyhood what a cardinal article of faith this prepossession had become. We were taught by our great and honoured master, Lyell, to believe implicitly in gentle and uniform operations, extended over indefinite periods of time, though possibly some, with the zeal of partisans, carried this belief to an extreme which Lyell himself did not approve. The most stupendous marks of terrestrial disturbance, such as the structure of great mountain chains, were deemed to be more satisfactorily accounted for by slow movements prolonged through indefinite ages than by any sudden convulsion.

What the more extreme members of the uniformitarian school failed to perceive was the absence of all evidence that terrestrial catastrophes even on a colossal scale might not be a part of the present economy of this globe. Such occurrences might never seriously affect the whole earth at one time, and might return at such wide intervals that no example of them has yet been chronicled by man. But that they have occurred again and again, and even within comparatively recent geological times, hardly admits of serious doubt. How far at different epochs and in various degrees they may have included the operation of cosmical influences lying wholly outside the planet, and how far they have resulted from movements within the body of the planet itself, must remain for further inquiry. Yet the admission that they have played a part in geological history may be freely made without impairing the real value of the Huttonian doctrine, that in the interpretation of this history our main guide must be a knowledge of the existing processes of terrestrial change.

As the most recent and best known of these great transformations, the Ice Age stands out conspicuously before us. If any one sixty years ago had ventured to affirm that at no very distant date the snows and glaciers of the Arctic regions stretched southwards into France, he would have been treated as a mere visionary theorist. Many of the facts to which he would have appealed in support of his statement were already well known, but they had received various other interpretations. By some observers, notably by Hutton's friend, Sir James Hall, they were believed to be due to violent debacles of water that swept over the face

of the land. By others they were attributed to the strong tides and currents of the sea when the land stood at a lower level. The uniformitarian school of Lyell had no difficulty in elevating or depressing land to any required extent. Indeed, when we consider how averse these philosophers were to admit any kind or degree of natural operation other than those of which there was some human experience, we may well wonder at the boldness with which, on sometimes the slenderest evidence, they made land and sea change places, on the one hand submerging mountain-ranges, and on the other placing great barriers of land where a deep ocean rolls. They took such liberties with geography because only well-established processes of change were invoked in the operations. Knowing that during the passage of an earthquake a territory bordering the sea may be upraised or sunk a few feet, they drew the sweeping inference that any amount of upheaval or depression of any part of the earth's surface might be claimed in explanation of geological problems. The progress of inquiry, while it has somewhat curtailed this geographical license, has now made known in great detail the strange story of the Ice Age.

There cannot be any doubt that after man had become a denizen of the earth, a great physical change came over the northern hemisphere. The climate, which had previously been so mild that evergreen trees flourished within ten or twelve degrees of the north pole, now became so severe that vast sheets of snow and ice covered the north of Europe and crept southward beyond the south coast of Ireland, almost as far as the southern shores of England, and across the Baltic into France and Germany. This Arctic transformation was not an episode that lasted merely a few seasons, and left the land to resume thereafter its ancient aspect. With various successive fluctuations it must have endured for many thousands of years. When it began to disappear it probably faded away as slowly and imperceptibly as it had advanced, and when it finally vanished it left Europe and North America profoundly changed in the character alike of their scenery and of their inhabitants. The rugged rocky contours of earlier times were ground smooth and polished by the march of the ice across them, while the lower grounds were buried under wide and thick sheets of clay, gravel, and sand, left behind by the melting ice. The varied and abundant flora which had spread so far within the Arctic circle was driven away into more southern and less ungenial climes. But most memorable of all was the extirpation of the prominent large animals which, before the advent of the ice, had roamed over Europe. The lions, hyænas, wild horses,

hippopotami and other creatures either became entirely extinct or were driven into the Mediterranean basin and into Africa. In their place came northern forms—the reindeer, glutton, musk ox, woolly rhinoceros, and mammoth.

Such a marvellous transformation in climate, in scenery, in vegetation and in inhabitants, within what was after all but a brief portion of geological time, though it may have involved no sudden or violent convulsion, is surely entitled to rank as a catastrophe in the history of the globe. It was probably brought about mainly if not entirely by the operation of forces external to the earth. No similar calamity having befallen the continents within the time during which man has been recording his experience, the Ice Age might be cited as a contradiction to the doctrine of uniformity. And yet it manifestly arrived as part of the established order of Nature. Whether or not we grant that other ice ages preceded the last great one, we must admit that the conditions under which it arose, so far as we know them, might conceivably have occurred before and may occur again. The various agencies called into play by the extensive refrigeration of the northern hemisphere were not different from those with which we are familiar. Snow fell and glaciers crept as they do to-day. Ice scored and polished rocks exactly as it still does among the Alps and in Norway. There was nothing abnormal in the phenomena save the scale on which they were manifested. And thus, taking a broad view of the whole subject, we recognise the catastrophe, while at the same time we see in its progress the operation of those same natural processes which we know to be integral parts of the machinery whereby the surface of the earth is continually transformed.

Among the debts which science owes to the Huttonian school, not the least memorable is the promulgation of the first well-founded conceptions of the high antiquity of the globe. Some six thousand years had previously been believed to comprise the whole life of the planet, and indeed of the entire universe. When the curtain was then first raised that had veiled the history of the earth, and men, looking beyond the brief span within which they had supposed that history to have been transacted, beheld the records of a long vista of ages stretching far away into a dim illimitable past, the prospect vividly impressed their imagination. Astronomy had made known the immeasurable fields of space; the new science of geology seemed now to reveal boundless distances of time. The more the terrestrial chronicles were studied the farther could the eye range into an antiquity so vast as to defy all attempts to measure or

define it. The progress of research continually furnished additional evidence of the enormous duration of the ages that preceded the coming of man, while, as knowledge increased, periods that were thought to have followed each other consecutively were found to have been separated by prolonged intervals of time. Thus the idea arose and gained universal acceptance that, just as no boundary could be set to the astronomer in his free range through space, so the whole of bygone eternity lay open to the requirements of the geologist. Playfair, re-echoing and expanding Hutton's language, had declared that neither among the records of the earth nor in the planetary motions can any trace be discovered of the beginning or of the end of the present order of things; that no symptom of infancy or of old age has been allowed to appear on the face of Nature, nor any sign by which either the past or the future duration of the universe can be estimated; and that although the Creator may put an end, as He no doubt gave a beginning, to the present system, such a catastrophe will not be brought about by any of the laws now existing, and is not indicated by anything which we perceive. This doctrine was naturally espoused with warmth by the extreme uniformitarian school, which required an unlimited duration of time for the accomplishment of such slow and quiet cycles of change as they conceived to be alone recognisable in the records of the earth's past history.

It was Lord Kelvin who, in the writings to which I have already referred, first called attention to the fundamentally erroneous nature of these conceptions. He pointed out that from the high internal temperature of our globe, increasing inwards as it does, and from the rate of loss of its heat, a limit may be fixed to the planet's antiquity. He showed that so far from there being no sign of a beginning, and no prospect of an end to the present economy, every lineament of the solar system bears witness to a gradual dissipation of energy from some definite starting-point. No very precise data were then, or indeed are now, available for computing the interval which has elapsed since that remote commencement, but he estimated that the surface of the globe could not have consolidated less than twenty millions of years ago, for the rate of increase of temperature inwards would in that case have been higher than it actually is; nor more than 400 millions of years ago, for then there would have been no sensible increase at all. He was inclined, when first dealing with the subject, to believe that from a review of all the evidence then available, some such period as 100 millions of years would embrace the whole geological history of the globe.

It is not a pleasant experience to discover that a fortune which one

has unconcernedly believed to be ample has somehow taken to itself wings and disappeared. When the geologist was suddenly awakened by the energetic warning of the physicist, who assured him that he had enormously overdrawn his account with past time, it was but natural under the circumstances that he should think the accountant to be mistaken, who thus returned to him dishonoured the large drafts he had made on eternity. He saw how wide were the limits of time deducible from physical considerations, how vague the data from which they had been calculated. And though he could not help admitting that a limit must be fixed beyond which his chronology could not be extended, he consoled himself with the reflection that after all a hundred millions of years was a tolerably ample period of time, and might possibly have been quite sufficient for the transaction of all the prolonged sequence of events recorded in the crust of the earth. He was therefore disposed to acquiesce in the limitation thus imposed upon geological history.

But physical inquiry continued to be pushed forward with regard to the early history and the antiquity of the earth. Further consideration of the influence of tidal friction in retarding the earth's rotation, and of the sun's rate of cooling, led to sweeping reductions of the time allowable for the evolution of the planet. The geologist found himself in the plight of Lear when his bodyguard of one hundred knights was cut down. 'What need you five-and-twenty, ten or five?' demands the inexorable physicist, as he remorselessly strikes slice after slice from his allowance of geological time. Lord Kelvin is willing, I believe, to grant us some twenty millions of years, but Professor Tait would have us content with less than ten millions.

In scientific as in other mundane questions there may often be two sides, and the truth may ultimately be found not to lie wholly with either. I frankly confess that the demands of the early geologists for an unlimited series of ages were extravagant, and even, for their own purposes, unnecessary, and that the physicist did good service in reducing them. It may also be freely admitted that the latest conclusions from physical considerations of the extent of geological time require that the interpretation given to the record of the rocks should be rigorously revised, with the view of ascertaining how far that interpretation may be capable of modification or amendment. But we must also remember that the geological record constitutes a voluminous body of evidence regarding the earth's history which cannot be ignored, and must be explained in accordance with ascertained natural laws. If the conclusions derived from the most careful study of this record cannot be reconciled with those drawn from physical

considerations, it is surely not too much to ask that the latter should be also revised. It has been well said that the mathematical mill is an admirable piece of machinery, but that the value of what it yields depends upon the quality of what is put into it. That there must be some flaw in the physical argument I can, for my own part, hardly doubt, though I do not pretend to be able to say where it is to be found. Some assumption, it seems to me, has been made, or some consideration has been left out of sight, which will eventually be seen to vitiate the conclusions, and which when duly taken into account will allow time enough for any reasonable interpretation of the geological record.

In problems of this nature, where geological data capable of numerical statement are so needful, it is hardly possible to obtain trustworthy computations of time. We can only measure the rate of changes in progress now, and infer from these changes the length of time required for the completion of results achieved by the same processes in the past. There is fortunately one great cycle of movement which admits of careful investigation, and which has been made to furnish valuable materials for estimates of this kind. The universal degradation of the land, so notable a characteristic of the earth's surface, has been regarded as an extremely slow process. Though it goes on without ceasing, yet from century to century it seems to leave hardly any perceptible trace on the landscapes of a country. Mountains and plains, hills and valleys, appear to wear the same familiar aspect which is indicated in the oldest pages of history. This obvious slowness in one of the most important departments of geological activity, doubtless contributed in large measure to form and foster a vague belief in the vastness of the antiquity required for the evolution of the earth.

But, as geologists eventually came to perceive, the rate of degradation of the land is capable of actual measurement. The amount of material worn away from the surface of any drainage-basin and carried in the form of mud, sand, or gravel, by the main river into the sea, represents the extent to which that surface has been lowered by waste in any given period of time. But denudation and deposition must be equivalent to each other. As much material must be laid down in sedimentary accumulations as has been mechanically removed, so that in measuring the annual bulk of sediment borne into the sea by a river, we obtain a clue not only to the rate of denudation of the land, but also to the rate at which the deposition of new sedimentary formations takes place.

As might be expected, the activities involved in the lowering of the

surface of the land are not everywhere equally energetic. They are naturally more vigorous where the rainfall is heavy, where the daily range of temperature is large, and where frosts are severe. Hence they are obviously much more effective in mountainous regions than on plains; and their results must constantly vary, not only in different basins of drainage, but even, and sometimes widely, within the same basin. Actual measurement of the proportion of sediment in river water shows that while in some cases the lowering of the surface of the land may be as much as $\frac{1}{730}$ of a foot in a year, in others it falls as low as $\frac{1}{6800}$. In other words, the rate of deposition of new sedimentary formations, over an area of sea-floor equivalent to that which has yielded the sediment, may vary from one foot in 730 years to one foot in 6,800 years.

If now we take these results and apply them as measures of the length of time required for the deposition of the various sedimentary masses that form the outer part of the earth's crust, we obtain some indication of the duration of geological history. On a reasonable computation these stratified masses, where most fully developed, attain a united thickness of not less than 100,000 feet. If they were all laid down at the most rapid recorded rate of denudation, they would require a period of seventy-three millions of years for their completion. If they were laid down at the slowest rate they would demand a period of not less than 680 millions.

But it may be argued that all kinds of terrestrial energy are growing feeble, that the most active denudation now in progress is much less vigorous than that of bygone ages, and hence that the stratified part of the earth's crust may have been put together in a much briefer space of time than modern events might lead us to suppose. Such arguments are easily adduced and look sufficiently specious, but no confirmation of them can be gathered from the rocks. On the contrary, no one can thoughtfully study the various systems of stratified formations without being impressed by the fulness of their evidence that, on the whole, the accumulation of sediment has been extremely slow. Again and again we encounter groups of strata composed of thin paper-like laminæ of the finest silt, which evidently settled down quietly and at intervals on the sea bottom. We find successive layers covered with ripple-marks and sun-cracks, and we recognise in them memorials of ancient shores where sand and mud tranquilly gathered as they do in sheltered estuaries at the present day. We can see no proof whatever, nor even any evidence which suggests, that on the whole the rate of waste and sedimentation was more rapid during Mesozoic and Palæozoic time than it is to-day. Had

there been any marked difference in this rate from ancient to modern times, it would be incredible that no clear proof of it should have been recorded in the crust of the earth.

But in actual fact the testimony in favour of the slow accumulation and high antiquity of the geological record is much stronger than might be inferred from the mere thickness of the stratified formations. These sedimentary deposits have not been laid down in one unbroken sequence, but have had their continuity interrupted again and again by upheaval and depression. So fragmentary are they in some regions, that we can easily demonstrate the length of time represented there by still existing sedimentary strata to be vastly less than the time indicated by the gaps in the series.

There is yet a further and impressive body of evidence furnished by the successive races of plants and animals which have lived upon the earth and have left their remains sealed up within its rocky crust. No one now believes in the exploded doctrine that successive creations and universal destructions of organic life are chronicled in the stratified rocks. It is everywhere admitted that, from the remotest times up to the present day, there has been an onward march of development, type succeeding type in one long continuous progression. As to the rate of this evolution precise data are wanting. There is, however, the important negative argument furnished by the absence of evidence of recognisable specific variations of organic forms since man began to observe and record. We know that within human experience a few species have become extinct, but there is no conclusive proof that a single new species has come into existence, nor are appreciable variations readily apparent in forms that live in a wild state. The seeds and plants found with Egyptian mummies, and the flowers and fruits depicted on Egyptian tombs, are easily identified with the vegetation of modern Egypt. The embalmed bodies of animals found in that country show no sensible divergence from the structure or proportions of the same animals at the present day. The human races of Northern Africa and Western Asia were already as distinct when portrayed by the ancient Egyptian artists as they are now, and they do not seem to have undergone any perceptible change since then. Thus a lapse of four or five thousand years has not been accompanied by any recognisable variation in such forms of plant and animal life as can be tendered in evidence. Absence of sensible change in these instances is, of course, no proof that considerable alteration may not have been accomplished in other forms more exposed to vicissitudes of climate and other external influences. But it

furnishes at least a presumption in favour of the extremely tardy progress of organic variation.

If, however, we extend our vision beyond the narrow range of human history, and look at the remains of the plants and animals preserved in those younger formations which, though recent when regarded as parts of the whole geological record, must be many thousands of years older than the very oldest of human monuments, we encounter the most impressive proofs of the persistence of specific forms. Shells which lived in our seas before the coming of the Ice Age present the very same peculiarities of form, structure, and ornament which their descendants still possess. The lapse of so enormous an interval of time has not sufficed seriously to modify them. So too with the plants and the higher animals which still survive. Some forms have become extinct, but few or none which remain display any transitional gradations into new species. We must admit that such transitions have occurred, that indeed they have been in progress ever since organised existence began upon our planet, and are doubtless taking place now. But we cannot detect them on the way, and we feel constrained to believe that their march must be excessively slow.

There is no reason to think that the rate of organic evolution has ever seriously varied; at least no proof has been adduced of such variation. Taken in connection with the testimony of the sedimentary rocks, the inferences deducible from fossils entirely bear out the opinion that the building up of the stratified crust of the earth has been extremely gradual. If the many thousands of years which have elapsed since the Ice Age have produced no appreciable modification of surviving plants and animals, how vast a period must have been required for that marvellous scheme of organic development which is chronicled in the rocks!

After careful reflection on the subject, I affirm that the geological record furnishes a mass of evidence which no arguments drawn from other departments of Nature can explain away, and which, it seems to me, cannot be satisfactorily interpreted save with an allowance of time much beyond the narrow limits which recent physical speculation would concede.

I have reserved for final consideration a branch of the history of the earth which, while it has become, within the lifetime of the present generation, one of the most interesting and fascinating departments of geological inquiry, owed its first impulse to the far-seeing intellects of Hutton

and Playfair. With the penetration of genius these illustrious teachers perceived that if the broad masses of land and the great chains of mountains owe their origin to stupendous movements which from time to time have convulsed the earth, their details of contour must be mainly due to the eroding power of running water. They recognised that as the surface of the land is continually worn down, it is essentially by a process of sculpture that the physiognomy of every country has been developed, valleys being hollowed out and hills left standing, and that these inequalities in topographical detail are only varying and local accidents in the progress of the one great process of the degradation of the land.

From the broad and guiding outlines of theory thus sketched we have now advanced amid ever-widening multiplicity of detail into a fuller and nobler conception of the origin of scenery. The law of evolution is written as legibly on the landscapes of the earth as on any other page of the Book of Nature. Not only do we recognise that the existing topography of the continents, instead of being primeval in origin, has gradually been developed after many precedent mutations, but we are enabled to trace these earlier revolutions in the structure of every hill and glen. Each mountain-chain is thus found to be a memorial of many successive stages in geographical evolution. Within certain limits, land and sea have changed places again and again. Volcanoes have broken out and have become extinct in many countries long before the advent of man. Whole tribes of plants and animals have meanwhile come and gone, and in leaving their remains behind them as monuments at once of the slow development of organic types, and of the prolonged vicissitudes of the terrestrial surface, have furnished materials for a chronological arrangement of the earth's topographical features. Nor is it only from the organisms of former epochs that broad generalisations may be drawn regarding revolutions in geography. The living plants and animals of to-day have been discovered to be eloquent of ancient geographical features that have long since vanished. In their distribution they tell us that climates have changed, that islands have been disjoined from continents, that oceans once united have been divided from each other, or once separate have now been joined; that some tracts of land have disappeared, while others for prolonged periods of time have remained in isolation. The present and the past are thus linked together not merely by dead matter, but by the world of living things, into one vast system of continuous progression.

In this marvellous increase of knowledge regarding the transformations of the earth's surface, one of the most impressive features, to my

mind, is the power now given to us of perceiving the many striking contrasts between the present and former aspects of topography and scenery. We seem to be endowed with a new sense. What is seen by the bodily eye—mountain, valley, or plain—serves but as a veil, beyond which, as we raise it, visions of long-lost lands and seas rise before us in a far-retreating vista. Pictures of the most diverse and opposite character are beheld, as it were, through each other, their lineaments subtly interwoven and even their most vivid contrasts subdued into one blended harmony. Like the poet, 'we see, but not by sight alone'; and the 'ray of fancy' which, as a sunbeam, lightened up his landscape, is for us broadened and brightened by that play of the imagination which science can so vividly excite and prolong.

Admirable illustrations of this modern interpretation of scenery are supplied by the district wherein we are now assembled. On every side of us rise the most convincing proofs of the reality and potency of that ceaseless sculpture by which the elements of landscape have been carved into their present shapes. Turn where we may, our eyes rest on hills that project above the lowland, not because they have been upheaved into these positions, but because their stubborn materials have enabled them better to withstand the degradation which has worn down the softer strata into the plains around them. Inch by inch the surface of the land has been lowered, and each hard rock successively laid bare has communicated its own characteristics of form and colour to the scenery.

If, standing on the Castle Rock, the central and oldest site in Edinburgh, we allow the bodily eye to wander over the fair landscape, and the mental vision to range through the long vista of earlier landscapes which science here reveals to us, what a strange series of pictures passes before our gaze! The busy streets of to-day seem to fade away into the mingled copsewood and forest of prehistoric time. Lakes that have long since vanished gleam through the woodlands, and a rude canoe pushing from the shore startles the red deer that had come to drink. While we look, the picture changes to a polar scene, with bushes of stunted Arctic willow and birch, among which herds of reindeer browse and the huge mammoth makes his home. Thick sheets of snow are draped all over the hills around, and far to the north-west the distant gleam of glaciers and snow-fields marks the line of the Highland mountains. As we muse on this strange contrast to the living world of to-day the scene appears to grow more Arctic in aspect, until every hill is buried under one vast sheet of ice, 2,000 feet or more in thickness, which fills up the whole midland valley of Scotland and creeps slowly eastward into the basin of

the North Sea. Here the curtain drops upon our moving pageant, for in the geological record of this part of the country an enormous gap occurs before the coming of the Ice Age.

When once more the spectacle resumes its movement the scene is found to have utterly changed. The familiar hills and valleys of the Lothians have disappeared. Dense jungles of a strange vegetation—tall reeds, club-mosses, and tree-ferns—spread over the steaming swamps that stretch for leagues in all directions. Broad lagoons and open seas are dotted with little volcanic cones which throw out their streams of lava and showers of ashes. Beyond these, in dimmer outline and older in date, we descry a wide lake or inland sea, covering the whole midland valley and marked with long lines of active volcanoes, some of them several thousand feet in height. And still further and fainter over the same region, we may catch a glimpse of that still earlier expanse of sea which in Silurian times overspread most of Britain. But beyond this scene our vision fails. We have reached the limit across which no geological evidence exists to lead the imagination into the primeval darkness beyond.

Such in briefest outline is the succession of mental pictures which modern science enables us to frame out of the landscapes around Edinburgh. They may be taken as illustrations of what may be drawn, and sometimes with even greater fulness and vividness, from any district in these islands. I cite them especially because of their local interest in connection with the present meeting of the Association, and because the rocks that yield them gave inspiration to those great masters whose claims on our recollection, not least for their explanation of the origin of scenery, I have tried to recount this evening. But I am further impelled to dwell on these scenes from an overmastering personal feeling to which I trust I may be permitted to give expression. It was these green hills and grey crags that gave me in boyhood the impulse that has furnished the work and joy of my life. To them, amid changes of scene and surroundings, my heart ever fondly turns, and here I desire gratefully to acknowledge that it is to their influence that I am indebted for any claim I may possess to stand in the proud position in which your choice has placed me.

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STATE OF SCIENCE.

Report of the Corresponding Societies Committee, consisting of Mr. Francis Galton (*Chairman*), Professor A. W. Williamson, Sir Douglas Galton, Professor Boyd Dawkins, Sir Rawson Rawson, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor R. Meldola (*Secretary*), Professor T. G. Bonney, Mr. W. Whitaker, Mr. G. J. Symons, General Pitt-Rivers, Mr. W. Topley, *and* Mr. T. V. Holmes.

The Corresponding Societies Committee of the British Association begs leave to submit to the General Committee the following Report of the proceedings of the Conference held at Cardiff.

The Council nominated Mr. G. J. Symons, F.R.S., Chairman, Dr. J. G. Garson, Vice-Chairman, and Professor R. Meldola, F.R.S., Secretary to the Conference. These nominations were confirmed by the General Committee at the meeting held at Cardiff on Wednesday, August 19. The meetings of the Conference were held on Thursday, August 20, at 3.30 P.M., and on Tuesday, August 25, at 1 P.M., in the Dumfries Street Proprietary School. The following thirty-six Delegates were nominated by the Corresponding Societies as their representatives at the Cardiff Meeting :—

Rev. H. H. Winwood, M.A., F.G.S.	Bath Natural History and Antiquarian Field Club.
Mr. John Brown	Belfast Natural History and Philosophical Society.
Mr. William Gray, M.R.I.A. . .	Belfast Naturalists' Field Club.
Mr. C. J. Watson	Birmingham Natural History and Microscopical Society.
Mr. J. Kenward, F.S.A. . .	Birmingham Philosophical Society.
Prof. A. Leipner	Bristol Naturalists' Society.
Mr. Peter Price Mr. T. H. Thomas Dr. C. T. Vachell . . .	Cardiff Naturalists' Society.[1]
Mr. M. H. Mills, F.G.S. . . .	Chesterfield and Midland Counties Institution of Engineers.

[1] Three Delegates appointed under the rule which empowers a Society having its headquarters in the place of meeting to nominate this number of representatives.

Mr. Thomas Cushing, F.R.A.S.	Croydon Microscopical and Natural History Club.
Mr. J. G. Goodchild, F.G.S.	Cumberland and Westmorland Association for the Advancement of Literature and Science.
Mr. A. S. Reid, M.A., F.G.S.	East Kent Natural History Society.
Mr. Henry Coates	East of Scotland Union of Naturalists Societies and Perthshire Society of Natural Science.
Prof. R. Meldola, F.R.S.	Essex Field Club.
Mr. D. Corse Glen, F.G.S.	Geological Society of Glasgow.
Dr. A. T. Brett	Hertfordshire Natural History Society and Field Club.
Mr. C. J. Alford	Hampshire Field Club.
Mr. P. M. C. Kermode	Isle of Man Natural History and Antiquarian Society.
Mr. B. Holgate, F.G.S.	Leeds Geological Association.
Mr. Osmund W. Jeffs	Liverpool Geological Society.
Mr. M. B. Slater, F.L.S.	Malton Field Naturalists' and Scientific Society.
Mr. Eli Sowerbutts, F.R.G.S.	Manchester Geographical Society.
Mr. Mark Stirrup, F.G.S.	Manchester Geological Society.
Dr. J. T. Arlidge, M.A.	North Staffordshire Naturalists' Field Club and Archæological Society.
Mr. C. A. Markham, F.S.A.	Northamptonshire Natural History Society and Field Club.
Prof. J. H. Merivale, M.A.	North of England Institute of Mining and Mechanical Engineers.
Mr. R. Robinson	Rochdale Literary and Scientific Society.
Mr. A. Silva White, F.R.S.E.	Royal Scottish Geographical Society.
Mr. E. Chisholm Batten	Somersetshire Archæological and Natural History Society.
Mr. F. W. Hembry, F.R.M.S.	South London Microscopical and Natural History Club.
Prof. C. F. Bastable, M.A.	Statistical and Social Inquiry Society of Ireland.
Mr. G. E. T. Smithson	Tyneside Geographical Society.
Mr. W. Andrews, F.G.S.	Warwickshire Naturalists' and Archæologists' Field Club.
Rev. J. O. Bevan, M.A.	Woolhope Naturalists' Field Club.
Rev. E. P. Knubley, M.A.	Yorkshire Naturalists' Union.

First Conference, August 20.

The chair was taken by Mr. G. J. Symons, F.R.S., the Corresponding Societies Committee being also represented by Sir Douglas Galton, Dr. Garson, Mr. W. Whitaker, Mr. W. Topley, and Professor R. Meldola as Secretary.

The Report of the Corresponding Societies Committee, printed copies of which had been circulated among the Delegates, was, on the motion of the Chairman, taken as read. The subjects treated of in the Report were then dealt with in the order of the Sections.

Section A.

Temperature Variation in Lakes, Rivers, and Estuaries.—Mr. Mark Stirrup stated that the Manchester Geological Society had been of some use in this inquiry. Some few years ago he had solicited the Water Committee of the Manchester Corporation to undertake observations in their large reservoirs at Woodhead, but although these were commenced,

a difficulty was soon experienced in finding reliable observers, and they had consequently to be given up. Mr. Watts had, however, at his request, taken the matter up with regard to the Oldham reservoirs, and had been at great pains to make trustworthy observations, which had received the warm approval of the Temperature Committee.

Mr. M. H. Mills thought that it might be advantageous if similar observations were extended to the temperature variations of underground waters.

The Chairman explained that there was already a Committee of the Association dealing with underground temperatures, and he suggested that they might extend their work to water as well as soil.

Meteorological Photography.—The Chairman stated that some progress had been made during the year with the work of this Committee, and they had been fortunate in obtaining some very good photographs of clouds, lightning, frost effects, &c. These photographs were exhibited in the meeting-room of Section A, and he invited the Delegates to inspect them. A report of what had been thus far done would be presented during the meeting, and he expressed the hope that the Delegates would assist the Committee by securing the co-operation of amateur photographers throughout the country.

Mr. Cushing presented two photographs showing the effects of a snowstorm taken during the previous winter.

Section C.

Geological Photography.—The Rev. J. O. Bevan announced that on his representation the Woolhope Club had recently appointed a Committee to deal with this subject, and he hoped that their efforts during the year would be of use to the Geological Photographs Committee.

Mr. O. W. Jeffs stated that the work of this Committee, of which he was Secretary, had made satisfactory progress during the year, and he expressed his thanks to the Corresponding Societies not only for the assistance which they had rendered by supplying photographs, but also for the interest which they had raised in different parts of the country. As a result of the work an exhibition of photographs had been arranged in the meeting-room of Section C. The total number of photographs received during the year was 300. With respect to amateur photographic societies Mr. Jeffs stated that their Committee had not yet received from them the assistance which they had hoped. Although a large number of people in England, Scotland, Ireland, and Wales had helped them, it was necessary to point out that what was now wanted was work of a more systematic character. The Yorkshire Naturalists' Union had sent in the largest number of photographs received from any one society. The East Kent Natural History Society had also formed a photographic section and had sent in the results, but in other parts of the country work had not been carried on to the same extent, and he hoped that some of the Delegates would advocate their cause and promote local photographic surveys on a systematic plan.

Mr. Wm. Gray remarked that the Committee must not be discouraged by the limited number of photographs which might be sent in during any particular year, because at the present stage, when the whole scheme was being organised, the number of photographs did not indicate the amount of work that was being done. Thus the Belfast Naturalists' Field Club

had been well represented last year, but would not be so well represented this year, because they were engaged in organising their work and preparing their own lists. When these were ready the work would progress more rapidly.

Mr. Cushing presented two photographs on behalf of the Croydon Microscopical and Natural History Club.

The Rev. H. H. Winwood raised a question with respect to the obtaining of copies of the photographs. The amateur photographer took the negatives, but did not wish to be troubled with multiplying prints. He thought it desirable that the name of the person holding the negative should be made known in order that copies of any particular photograph might be obtained.

Mr. Gray stated that this was one of the points which had been considered by their Society in Belfast, and they proposed to inform the public where copies of the photographs were to be obtained.

Mr. Sowerbutts said he knew a considerable number of amateur photographers who would not send away their negatives to be printed from, nor would they allow prints to be made without their consent. He had tried to do something for the Committee with amateur photographers in Lancashire, but had found that the amateur who went out to photograph did not usually confine himself to such subjects as were required by the Committee. About 120 negatives had been taken by the Manchester Geographical Society, but these had not been taken specially for geological purposes, and only four had been sent to the Committee. The Manchester Geological Society, represented by Mr. Mark Stirrup, took photographs for scientific and not for mere pictorial purposes, and these would, no doubt, be of greater value. Their Geographical Society had, however, arranged to take a series across Lancashire for their own purposes, and any of the photographs showing geological features would, he thought, be at the service of the Committee.

Mr. Jeffs said that, in order to remove any misconception which might exist with respect to the purpose of the Committee, he would state that their first object was to have a typical collection of photographs illustrating the geological features of the country. Their next object was to enable teachers and lecturers to have copies of any of the photographs that might be desired. In furtherance of this object they had already published in their Report for 1890,[1] and had continued in their present Report, a list of photographs, giving particulars and the name of the photographer from whom they could be procured. Any person wanting copies could obtain them by writing. Of course the fixing of price was a local matter and beyond the control of the Committee; he thought that some of the photographers might be generous enough to present copies in the interests of science. Mr. Jeffs added that their Committee could not undertake to hold the negatives.

Mr. C. J. Watson suggested that copies of the photographs should be circulated among the Corresponding Societies, as they could not tell from the published list which of the photographs would be of use to a local Society. He thought that this would be met by having an album of duplicate prints for circulation in the manner suggested.

Mr. A. S. Reid said that he had been engaged for some time in inciting the local Societies to take up this work. He found that the amateur

[1] *B. A. Report*, Leeds, 1890, p. 429.

geologist was not inclined to add to the weight which he had to carry. The appliances for taking good photographs need not, however, be very heavy, as he had been experimenting with an ordinary hand camera, weighing five pounds, which he had carried over some of the rockiest parts of Scotland. He had contributed a short paper to the 'Photographic Quarterly' for January 1891, showing what could be done with one of these small cameras. Mr. Reid exhibited a print taken from one of these quarter-plate negatives, which he considered quite good enough for preparing larger diagrams from for teaching and lecturing purposes.

Mr. Holgate expressed his regret that the Committee could not undertake the care of the negatives, as he was of opinion that many photographers would be willing to take two negatives of any section, one for the use of the Committee, for the purpose of supplying prints at some fixed charge to the societies or individuals requiring them.

The Chairman stated that the Meteorological Photographs Committee had never experienced any of the difficulties referred to with respect to the negatives; those who took the photographs were in all cases willing that free use should be made of them by the Committee, and he expressed the hope that in the interests of science it might be the same with kindred subjects.

Sea Coast Erosion.—Mr. Topley said that a mass of information had been accumulated by this Committee, and it had been decided to conclude their work this year. For some parts of the country the records were fairly full, but for other parts very meagre. He mentioned that the French Government had appointed a commission to do similar work, which had adopted the form of questions circulated by this Committee.

Section D.

Disappearance of Native Plants.—Mr. D. Corse Glen reported that two papers on this subject had been sent in to the Committee by the Perthshire Society of Natural Science, but these had apparently not been made use of.

The Rev. E. P. Knubley explained that the Committee probably intended to confine their report this year entirely to Wales and the adjoining counties in the West of England. In view of the meeting being at Edinburgh next year, it was likely that the Perthshire lists would be taken for the next report.

Destruction of Wild Birds' Eggs.—Dr. Vachell said that the Cardiff Naturalists' Society had taken up a case in 1890 with respect to the destruction of birds and eggs on the island of Grassholme, in the Bristol Channel. A Bill had been introduced into Parliament last year by Mr. Pease, but this had unfortunately not been proceeded with. The protection of the birds, and of the eggs during the breeding season, was a very important matter, and he would be very glad if the Delegates would give some practical aid with the object of furthering the Bill.

The Chairman suggested that a recommendation from the Committee of Section D, backed up by a similar recommendation from the Conference, might be sent up to the Council through the Committee of Recommendations.

Dr. Garson concurred with this suggestion; he thought that the recommendation might be referred to the Council directly by the Sectional Committee.

Mr. Kermode said that in the Isle of Man they did protect the eggs as well as the birds, and he hoped that they would succeed in getting similar protection in Great Britain.

SECTION E.

Teaching of Geography in Primary Schools.—Mr. Sowerbutts said that he had not received any communications on this subject from the Delegates, so that he could make no statement beyond what he had gathered in a general way as to the education in the Manchester district. He distributed among the Delegates a report on geographical education which had been presented to the Council of the Manchester Geographical Society, and which contained evidence of very great improvement in the teaching of this subject. They had communicated with all the primary schools in Lancashire and Yorkshire, offering to conduct examinations and to give prizes. Replies had been received from three School Boards, a number of children had sat for examination, and all the prizes had been awarded. The two difficulties which had been met with were, first, the pressure of time in primary schools; and, secondly, that geography was not a compulsory subject under the Code. He considered the report itself as of great interest and value. One paper by Mr. Cardwell, of St. Bede's College, might almost be used as a text-book by any teacher who would adopt it for his pupils. Mr. Sowerbutts expressed his willingness to follow up the subject, which in his opinion had not received much encouragement from the Government Departments, and he added that if the Delegates would refer to the report which he had circulated, and communicate with him, he should be in a position to give a report at the next meeting.[1]

Ordnance Maps.—The Chairman stated that at the Leeds meeting last year a strong recommendation had been sent up to the Council as to the cost, the antiquity, and the difficulty of procuring copies of the Ordnance maps. The Council had communicated with Mr. Chaplin, of the Board of Agriculture, and they had heard unofficially that material alterations would be made, so that these maps would be very much more accessible than heretofore. He added that, so far as his experience went, nineteen-twentieths of the people of this country did not know how to make use of an Ordnance map.[2]

Mr. Holgate said that it would be desirable to have the contours of different heights printed in different colours. It would then be easy for teachers to get their pupils to trace out these contours and cut them out in cardboard. For teaching geography in an interesting way they could not, in his opinion, have anything better than a raised map, made in this manner.

Mr. Peter Price mentioned, as an illustration of the slow progress of

[1] Communications to be addressed to Mr. Eli Sowerbutts, 44 Brown Street, Manchester.

[2] The following resolutions were referred by the General Committee to the Council for consideration and action if desirable at the Cardiff meeting:—

(1) 'That the publication of the one-inch and six-inch Ordnance Survey Maps is, in the interests of Science, urgently required at the earliest possible date, no less than in the interests of Industry, Manufacture, and Technical Education.

(2) That steps be taken and provision made for keeping the Ordnance Maps up to date.

(3) That the Maps should be made more accessible to the public, and should be sold at a lower price, as is the case in nearly all other official publications, such as Admiralty Charts, Blue Books, &c.'

the survey, that the town of Cardiff had purchased new maps, which had been found to show only about one-half the present town. The survey had been made ten years ago, and the maps were quite useless for the purpose for which they had been purchased.

Mr. Mills said that it was only fair to state that he had never written to Stanford's for any map without receiving it by return of post.

Mr. Gray was of opinion that the maps should be sent gratuitously to schools. The children often had no idea of what a map meant, and they should have the maps of their own districts on different scales, in order that they might gain a better knowledge of geography.

The Chairman stated that he had recently been to Clevedon, and had been unable to procure the Ordnance map from the best shop in the town. He had written to Stanford and obtained one in two days, and had found that the map was twelve years old.

Mr. Whitaker said that there was no difficulty in getting one-inch maps with the contours printed on them, as the Ordnance Survey was now engaged in producing such maps. The work required time, however, as the copper plate of a one-inch map took a year to engrave. If the Government could be forced into using photo-zincography the maps might be produced more rapidly. He knew that nearly all the one-inch maps were to be procured with contours, although not with hill shading. Processes were now being tried at Southampton for printing in the hill shading in a transparent ink which would not obscure the lettering, the roads, rivers, or contour lines, &c. The chief delay occurred in the engraving, but the maps were always dated. With respect to the six-inch maps, Mr. Whitaker said that local surveyors or anyone who could pace accurately could fill in new features for themselves. In condemning a map as being of no use, all that was meant was that the new features had not been put on it, and that, of course, was bound to happen in growing towns like Cardiff, Manchester, and Southampton. The Government did not give the Survey the means of going over the ground again. The only way of hastening matters and of insuring the insertion of the latest features would be to influence the Treasury, which controls all the Government Departments.

Mr. Sowerbutts expressed his belief that the delay was mainly in the method of producing the maps. He had been surprised at the facility with which the Survey maps were produced in Brussels for about fourpence each directly from the zinc plates.

Mr. Kenward expressed his admiration for the one-inch Ordnance map. He said that he had made forty or fifty journeys on foot through every part of North Wales and had never found the map at fault.

Section G.

Flameless Explosives.—Professor Merivale stated that there was nothing new to report this year. The work was still going on, and next year they would have something definite to bring before the Delegates.

Mr. Mills said that the Chesterfield and Midland Counties Institution had been carrying on similar experiments, and it was to be regretted that both institutions were spending money and time over the same work.

The Chairman expressed the hope that they would combine to carry on the experiments together.

SECTION H.

Aid in Anthropological Exploration.—Dr. Garson stated that at last year's Conference he had called attention to the existence of a Committee for giving advice on this subject. As an illustration of the evil arising from neglecting the assistance thus offered he mentioned a case which had come under his notice during the year, in which a large barrow had been opened at a cost of 100*l*. A large number of valuable skeletons had been found, but only the skulls and a few long bones of at most three of the skeletons had been sent to him to work up; the rest of the bones had not been preserved. Thus a barrow with a number of skeletons had been simply destroyed and the money wasted. The exploration had been done as a piece of local work, and if application had been made to the Committee of Aid they could have given directions or sent some one down to assist the local Committee. Dr. Garson pointed out that the Committee of Aid did not propose to take the work out of the hands of, or to lay claim to the credit due to, local effort; they wished only to give assistance and advice. He therefore urged the Delegates to bring the existence of this Committee under the notice of their Societies.

Dr. Vachell said that he could bear out the remarks made by Dr. Garson. Some Roman remains had been found at Llantwit Major, amongst them being some very fine skeletons. Permission had been obtained to carry on excavations, but they were uncertain whether they would be stopped, and ultimately they were prevented from carrying on the work. Several skulls were obtained, but not the remaining portions of the skeletons, as they had no means at hand of preserving the bones, which in a few days crumbled to pieces. The skulls were sent to General Pitt-Rivers, who reported that these were of no use without the other parts of the skeletons.

Registration of Prehistoric Remains.—Dr. Garson said that the Secretary of this Committee, Mr. J. W. Davis, was not present at the Cardiff Meeting, but a report had been presented to Section H.

The Rev. J. O. Bevan stated that the Woolhope Naturalists' Field Club had decided to prepare a map showing the antiquities in their county. It was to be based on the prospectus issued by the Society of Antiquaries, and they wished to produce a map similar to that which had been prepared for Kent. They were going to appoint representatives in every parish, and to request them to send particulars of any objects of interest and to enter the positions of such objects on the Ordnance maps. He had been empowered by his Society to ask any of the Delegates who might have seen other schemes to furnish any hints that might be of use before they issued their own prospectus.

Dr. Garson suggested that those who were undertaking this kind of work should communicate with the Secretary of the Prehistoric Remains Committee of the British Association,[1] as that Committee was making a record of all ancient remains throughout the country, and they had a system which it would be desirable to adopt in order to bring all the records into harmony.

Mr. Kenward approved of this suggestion.

Mr. Whitaker requested the Delegates to communicate any discoveries of or concerning ancient remains to the Ordnance Survey. They would often find errors of omission in the maps, or the periods of antiquities

[1] Mr. J. W. Davis, Chevinedge, near Halifax.

definitely stated although still under discussion by archæologists. If errors of this kind were communicated to the Director-General of the Ordnance Survey they would be attended to. As an instance he mentioned that a member of the Hampshire Field Club had discovered a British earthwork which was not on the map; this omission had been made known to the Survey, and it was now being or would be surveyed and inserted.

Mr. Kenward stated that he had been able to do a similar thing in the case of the unnoted Roman camp at Metchley Park, near Birmingham.

Second Conference, August 25.

The chair was taken by Mr. G. J. Symons, F.R.S., the Corresponding Societies Committee being further represented by Sir Douglas Galton, Mr. Whitaker, Dr. Garson, and Professor Meldola as Secretary.

Section A.

Temperature Variation in Lakes, Rivers, and Estuaries.—Dr. H. R. Mill, the Secretary of this Committee, stated that last year the Committee had been recommended to draw up its fourth and final report. The report which had been presented took the form of a discussion of the observations which had been made during the past three years chiefly through the agency of the various Corresponding Societies. Their Committee had been appointed about the time when the Conference of Delegates had taken shape, and it was one of the first pieces of work recommended to be taken up. The object was to ascertain by observations, taken twice daily, the temperature of rivers, estuaries, and lakes in all parts of the kingdom. A very good beginning was made in England, Scotland, and Ireland, but unfortunately the Irish observations were not continued, some of the observers writing to say that they had commenced observations but were tired of them, and others that they could see no good in them. The Cardiff Naturalists' Society had distinguished itself by the energy with which the subject had been taken up. Dr. Mill exhibited a diagram which he had prepared, showing the results of two sets of observations, the first set made in the River Taff in the Castle grounds, and the second set in the Bristol Channel from one of the lightships. The curve drawn from the first set showed the temperature during the winter months and the way it varied, falling greatly during cold weather and rising rapidly during warm weather. The curve drawn from the second set showed that the water in the Channel was generally at a higher temperature, and that it kept its temperature more uniformly. In fact the temperature frequently rose when the land temperature fell, and fell when the land temperature rose. The subject had also been investigated by the Fishery Board of Scotland, whose report was being published. The observers at Rochdale and Oldham had also made an extremely valuable series of observations, some of which had been published by the Rochdale Society. The same thing had been done by the Manchester Geological Society in connection with the Oldham observations to which he had referred. The East Kent Natural History Society had made careful observations in the River Stour, which were accompanied by a series of reports drawn up by Colonel Horsley. These reports would be published *in extenso*. Observations had been made in the sea at Dover with the object of ascertaining whether any difference was pro-

duced by the current running from the North Sea to the Atlantic, or from the Atlantic to the North Sea, but the result was negative. The complete list of local societies which had interested themselves in the work was a very considerable one, and he mentioned only those whose contributions were most valuable. In addition to the Cardiff, East Kent, and Manchester Geological Societies, the Northamptonshire, Burton-on-Trent, and Rochdale Societies had all done admirable work. At Knaresborough one of the members of the Yorkshire Naturalists' Union had made some of the most interesting observations of all, because he had taken the readings in conjunction with the air temperature, and also the earth temperature, thereby bringing out in a very interesting way the great activity of the surface water in responding to changes in the atmosphere. This observer had also made a number of most admirable observations under the ice during the severe winter of last year. He found that in the first spell of freezing the average temperature under the ice was under 34°. There was a thaw and another frost, and it fell to 33°. Another thaw followed, and then a third frost, and it was only during the third period of freezing that the average temperature of the water came down to 32°. It was very fortunate that the work of the Committee had been extended over last year, and that the observers had met with such favourable conditions. He thanked the Delegates, the observers, and the Secretaries for the completeness with which the observations had been carried out. In several cases the observers had carried on the work on their own account, and he trusted that such observations would be continued and extended. Dr. Mill, in conclusion, expressed his willingness to render all possible assistance to such observers.

The Chairman said that for some reasons he regretted that the work of this Committee had come to an end, but he thought that their efforts had prepared the way for future organisation. He did not see why the Royal Meteorological Society, which dealt with the question of air and earth temperatures, should not deal with water temperature. Neither did he see why the Scottish Meteorological Society should not deal with this subject. He was inclined to hope that these two Societies might make some arrangement for conducting and co-ordinating such observations.

Meteorological Photography.—Mr. A. W. Clayden, the Secretary of this Committee, stated that although a large number of circulars had been sent to the various local Societies asking for contributions of meteorological photographs very few had as yet responded. The majority of the photographs which had been sent had come from isolated observers. He therefore urged the Delegates to bring the subject before their Societies, with a view to securing organised co-operation.

Section B.

Inquiry into the Condition of the Atmosphere of Manufacturing Towns.—Professor Meldola said that he had received a letter from Mr. J. R. Ashworth, the Secretary of the Rochdale Literary and Scientific Society, asking whether it would be of use for the British Association to appoint a Committee for this subject, which was attracting some attention in Manchester at the present time.

Mr. Mark Stirrup said there was a Committee in Manchester busy collecting information with respect to the exceptional atmosphere of that

town and its effect on vegetation and the health of the community.[1] The investigation was going on, and the report would be published by the Society; if any of the Delegates desired copies he would be happy to forward them on application. He suggested that other towns might be induced to carry on similar work.

The Chairman said that the Manchester Corporation had recently started a meteorological observatory in the centre of the town under the guidance of Dr. Tatham. He referred to the use of ozone papers, which had been shown by chemists to be coloured by several other gases besides ozone. Thirty years ago he had made some experiments in London with identical test-papers, which had been exposed in different parts of the town. He found that, in whichever direction the wind blew, the air coming from the country always coloured the papers more or less, but air which had passed over the town always lost the power of colouring the papers. It appeared to him that some simple test of this kind was wanted if it could only be made reliable. Mr. Symons also called attention to the fact that the Royal Horticultural Society had appointed a Committee for investigating the atmosphere of London in relation to fog and plant life.

Dr. Mill referred to the excellent work which the late Professor Carnelley had carried out in connection with the determination of the number of micro-organisms present in the atmosphere of rooms, &c.

Section C.

Geological Photography.—Mr. A. S. Reid said that their Committee had met since the last Conference, and had arrived at certain conclusions, which would be made known in due course. They had applied for a grant for the purpose of mounting the photographs, and a systematic method had been agreed upon, so that the prints could be mounted and handled without injury. The subject of lantern slides had been mentioned, but they had decided that the collecting of these did not come within their province.

Earth Tremors.—The Chairman stated that this Committee had during the past year been collecting apparatus and diagrams of apparatus for recording earth tremors. They had not yet come to any decision as to the best form of instrument, and they would be glad of any suggestions from those interested in the subject.[2] Application had been made for reappointment without a grant.

Section D.

Disappearance of Native Plants.—The Rev. E. P. Knubley reported that the Committee had been reappointed. From what had been said at the last meeting of the Conference he said that he might conclude that it was the wish of the Delegates that the reports from the North of England and Scotland should be incorporated in next year's report. The Committee for investigating the Invertebrate Fauna and Cryptogamic Flora of the British Isles had not been reappointed.

Destruction of Wild Birds' Eggs.—Dr. Vachell said that this subject

[1] The Town Gardening Committee of the Manchester Field Naturalists' and Archæologists' Society. The Secretary is Mr. Alfred Griffiths, 16 Kennedy Street, Albert Square, Manchester [Sec. Corres. Soc. Comm.].

[2] The Secretary of the Committee is Mr. C. Davison, 38 Charlotte Road, Birmingham.

had been brought forward at the meeting of the Sectional Committee, and a Committee had been recommended for appointment. It had been suggested to him by Professor Meldola that the action of the Committee might be strengthened if the matter were again brought under the notice of the local societies throughout the country through the Delegates at the present Conference, and he therefore detailed the facts which had led to the proposal for the formation of a Committee. In March 1890 the Cardiff Naturalists' Society had visited the island of Grassholme, and while there observing the habits of some of the wild birds a number of young men from one of H.M. steamships had landed and shot puffins and gulls, and wantonly destroyed a large number of the eggs. The affair had been fully reported in the 'Daily Graphic' at the time. As there seemed to be a wholesale destruction of wild birds' eggs going on, the matter had been brought forward last year in Parliament by Mr. Pease, and at the time he (Dr. Vachell) had done what he could to bring it under the notice of the local societies. He had also called the attention of their Members of Parliament to the subject, but the latter had taken the view that it was not very serious, and that when boys were home for their holidays they could not be prevented from taking birds' eggs. Mr. Pease's Bill proposed to render the destruction of wild birds' eggs prohibitory under a penalty not exceeding 5*s*. each egg, and left action to county councils in England and the magistrates and quarter sessions in Ireland. They did not wish to pin themselves to the exact text of Mr. Pease's Bill, but they wanted some legislation for the better protection of wild birds' eggs. He therefore moved: 'That a Committee be appointed to take steps for furthering legislative enactment for the better protection of wild birds' eggs.' [1]

Mr. Mills was opposed to the resolution, because in his opinion there were a great many birds which did harm. He thought that it was necessary for the welfare of the country and the preservation of game that such birds should be destroyed.

Professor Leipner said it was not proposed to include all birds in the Bill; it left liberty of action to the county councils, and he was in favour of its becoming law.

Mr. Chisholm Batten expressed his belief that there would be some difficulty in getting the law efficiently carried out.

Mr. Hembry approved of the resolution, and said that some good would be done even if the law were only partially carried out.

The Chairman pointed out that there had, no doubt, been an abuse, and it should, if possible, be checked. The proposal was as yet in its first stage, and all action would rest with the county councils and the justices, to whom he thought the proper administration of the law might very well be left. As it stood, the proposal did not appear to him to do harm to anybody's interests, and it did not follow that because such a law might be in existence any person who took a bird's egg would necessarily be fined 5*s*.

Mr. Slater remarked that gamekeepers were in the habit of destroying birds of prey because the latter destroyed the game. The balance of nature was thus upset, and the small birds allowed to increase and to destroy the crops.

[1] The following is the resolution passed by the General Committee: 'That Mr. Thomas Henry Thomas (Chairman), Dr. C. T. Vachell (Secretary), Professors W. N. Parker, Newton, and Leipner, Mr. Poulton, and Canon Tristram be a Committee to consider proposals for the Legislative Protection of Wild Birds' Eggs.'

Dr. Vachell said that the proposal to form a committee had been seconded in Section D by Canon Tristram, who had strongly advocated three Bills which had passed through the House of Commons, and whose extensive practical knowledge of the subject was beyond question.

The resolution was finally put to the meeting and carried with one dissentient.

Popularising of Natural History Studies.—Professor Merivale said that it might interest the Delegates to learn what was being done in Newcastle to popularise natural history, especially among young people. They had a 'Dicky Bird Society,' numbering some 220,000 members, and articles were published from time to time in the 'Newcastle Weekly Chronicle.' One hundred and twenty species of birds had already been described and illustrated, and the whole series, when complete, would be republished in a separate form.

Mr. Sowerbutts also alluded to the useful dissemination of geographical and zoological knowledge through the same publication ('Newcastle Weekly Chronicle'), and spoke in high terms of the illustrations, which, especially in the case of the birds, had been executed with remarkable success by some photo-mechanical process.

Botanical Demonstrations for Teachers. — Professor Leipner called attention to this subject, and invited all teachers in public, private, and Board schools to attend two demonstrations at University College, Bristol. His plan was to select three or four familiar wild flowers and demonstrate their structure by means of diagrams on the blackboard. The experiment had been tried one year, and had been so successful that he had been asked to repeat it a second year.

Section H.

Description of Museum Specimens.—Dr. Garson said that it was very necessary for all workers in anthropology to know where specimens were preserved, especially in the case of local museums. It was sometimes impossible to visit these museums personally, and the best thing under the circumstances was to have a good description of the different specimens. This was a subject which the members of local societies might very well take up. Not only should the implements and other finds be described, but the conditions under which they were found should be carefully and completely recorded.

Registration of Prehistoric Remains.—Dr. Garson announced that this Committee, of which Mr. J. W. Davis was the secretary, had been reappointed. He urged upon the Delegates the importance of assisting in this work, and asked those who desired information as to the method of recording to communicate with Mr. Davis.

Aid in Anthropological Exploration.—Dr. Garson made some further remarks on this subject in continuation of the observations which he had made at the last Conference. He said that there was a general notion that in the case of human remains the skull was the only part of the skeleton worth preserving. This was a great mistake. The skull was undoubtedly valuable, but no less valuable were the other parts of the skeleton, particularly the long bones and the pelvis. Great care should be taken to preserve all bones and to keep the bones of each skeleton separate, so that the stature and other characteristics of each individual skeleton could be ascertained. It happened sometimes from

want of knowledge on the part of those engaged in excavations that after the exploration was completed all the bones except the skull had been reinterred. In some cases sentimentality came into question, and he instanced a case where, in deference to the wishes of the proprietor's wife, some extremely valuable remains had been reinterred and thus lost to anthropological science. He recommended skeletons to be sent to anthropological museums in preference to being preserved by individuals. Thus he knew of a case where at the death of the excavator some valuable skeletons he possessed were buried by his executors, and would have been entirely lost but that a friend of his having heard of the circumstance promptly dug them up, and they were now in an anthropological museum.[1]

Mr. Kenward said that, with reference to the registration of ancient remains, it would be a good thing if Mr. Davis would issue a short circular of instructions, so as to secure uniformity of results. He mentioned that the Society of Antiquaries had been working in the same direction and had appointed local secretaries in different parts of the country.

The Rev. J. O. Bevan also expressed a desire for information respecting the best form of prospectus to issue on behalf of the Woolhope Club, which, as he had stated at the last Conference, had decided to take up the subject of the registration of ancient remains.

The Chairman remarked upon the desirability of having uniformity of method in this work, and thought that the Society of Antiquaries would be the most efficient body for organising the whole system.

Dr. Garson agreed with this, and, in reply to a question by Mr. Kenward, he stated that the simplest means of estimating the stature of a body from the remains was to measure the femur and the tibia, making the measurements with extreme care and using the metric system. The spike on the upper surface of the tibia was not to be included in the measurement, and the femur was to be measured along its greatest length, the head and inner surface of the lower end of the bone lying in the same plane.

Interchange of Publications.—Among subjects of general interest discussed at the Conference was the importance of the Corresponding Societies freely interchanging their Transactions, Proceedings, and other publications. It was pointed out that, while printing, the additional cost of an extra 50 or 100 copies would be very trifling. Many of the Corresponding Societies are already in the habit of sending their publications to kindred Societies. The Hampshire Field Club deposits all such publications in the Southampton Public Library, so as to render them freely accessible.

On the motion of Mr. Holgate a vote of thanks was passed to the Chairman for presiding at the Conferences.

The Committee recommends the addition of the following Societies to the list:—

1. The Federated Institution of Mining Engineers.
2. The Liverpool Geographical Society.

On the other hand it has to announce the withdrawal of the Royal Scottish Geographical Society.

[1] Communications for the Committee of Aid to be addressed to the Secretary of the Anthropological Institute, 3 Hanover Square, London, W.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Barnsley Naturalists' and Scientific Society, 1867	Barnsley Nat. Sci. Soc.	Henry Wade, 10 Pitt Street . .	60	None	6*s.* and 10*s.* 6*d.*	Transactions, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C. .	W. W. Martin, Royal Literary and Scientific Institution, Bath	90	5*s.*	10*s.*	Proceedings, annually.
Bedfordshire Natural History Society and Field Club, 1875	Beds. N. H. Soc. F. C. .	T. Gwyn Elger, F.R.A.S., Beaumont House, Shakespeare Road, Bedford	1,000	None	25*s.* and 10*s.* 6*d.*	Transactions, occasionally.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	270	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C. .	Museum, College Square. R. Lloyd Praeger, B.E.	323	None	5*s.*	Report and Proceedings, annually.
Birmingham Natural History and Microscopical Society, 1858	Birm. N. H. M. Soc. .	W. H. Wilkinson and W. P. Marshall, Mason College, Birmingham	200	None	1*l.* 1*s.*	'Midland Naturalist,' monthly.
Birmingham Philosophical Society .	Birm. Phil. Soc. . .	T. W. Bridge and J. Landon, Medical Institute, Edmund Street, Birmingham	105	None	1*l.* 1*s.*	Proceedings, annually.
Bristol Naturalists' Society, 1862 .	Bristol Nat. Soc. . .	University College, Bristol. Professor Adolph Leipner, 38 Hampton Park, Redland, Bristol	217	5*s.*	10*s.*	Proceedings, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	46 High Street. G. Harris Morris, Ph.D., F.I.C., 6 Alexandra Road, Burton-on-Trent	221	None	5*s.*	Annual Report. Transactions occasionally.
Cardiff Naturalists' Society, 1867 .	Cardiff Nat. Soc. .	R. W. Atkinson, B.Sc., F.I.C., 44 Loudoun Square, Cardiff	400	None	10*s.* 6*d.*	Report and Transactions, half-yearly
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci. .	Grosvenor Museum, Chester. G. R. Griffith	650	None	5*s.*	Annual Report. Proceedings occasionally.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15 Cavendish Street, Chesterfield	267	1*l.* 1*s.*	Members 31*s.* 6*d.*; Subscribers 21*s.*; Associates and Students 20*s.*	Transactions of Federated Institution of Mining Engineers, about every two months.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	350	None	Minimum, 10*s.* 6*d.*	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc. .	G. B. Millett, Penzance	100	None	1*l.* 1*s.*	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C. .	Public Hall, Croydon. Walter Budgen	290	None	10*s.*	Proceedings and Transactions, annually.
Cumberland and Westmorland Association for the Advancement of Literature and Science, 1876	Cumb. West. Assoc. .	J. B. Bailey, 28 Eaglesfield Street, Maryport	848	None	6*s.*	Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C. .	N. M. Richardson. Montevideo, Chickerel, Weymouth	280	None	10*s.*	Proceedings, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. E. J. Chinnock, Fern Bank, Maxwelltown, Dumfries	204	2*s.* 6*d.*	5*s.*	Transactions and Journal of Proceedings, annually.
East Kent Natural History Society, 1857	E. Kent N. H. Soc. .	39 St. George's Street, Canterbury. W. P. Mann, B.A., Langton School	73	None	Ladies 5*s.*; Gentlemen 10*s.*	'South Eastern Naturalist,' occasionally.

SELECTED LIST OF SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, 12 Townsend Crescent, Kirkcaldy, N.B.	9 Societies, 1,008 Membs.	None	Assessment of 4*d.* per member	Proceedings, annually.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	H. M. Cadell, 5 St. Andrew Square, Edinburgh	226	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, 7 Knighton Villas, Buckhurst Hill, Essex	450	10*s.* 6*d.*	15*s.*	'Essex Naturalist,' monthly.
Federated Institution of Mining Engineers	Fed. Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,400	None	None	Transactions, about every two months.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. B. Murdoch, Capelrig, Mearns, Glasgow	240	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	D. A. Boyd and J. Steel, 207 Bath Street, Glasgow	325	7*s.* 6*d.*	7*s.* 6*d.*	Proceedings and Transactions, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	John Mayer, 207 Bath Street, Glasgow	692	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually; occasional papers.
Hampshire Field Club, 1885	Hants. F. C.	Hartley Institution, Southampton. W. Dale	250	None	7*s.* 6*d.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	Dr. J. Morison, F.G.S., St. Albans, and F. M. Campbell, F.L.S., Hoddesdon	255	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	75	10*s.*	10*s.*	Proceedings, usually every two years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	F. A. Black, 16 Union Street, Inverness	167	None	5*s.* and 2*s.*	Transactions, occasionally.
Ireland, Royal Geological Society of, 1831	R. Geol. Soc. Ireland	Prof. W. J. Sollas, F.R.S., Trinity College, Dublin	140	None	1*l.* 1*s.*	Journal, generally annually.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	W. F. Bailey, Prof. Bastable, and J. Pim, 35 Molesworth Street, Dublin	102	None	1*l.*	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Wm. Lower Carter, F.G.S., Meanwood, Leeds	141	None	5*s.*	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1878	Leeds Nat. C. Sci. Assoc.	80 Municipal Buildings, Victoria Square, Leeds. Arthur Walker	251	6*s.*	6*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	J. M. Gimson, Town Museum, Leicester	303 Membs., 32 Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc.	R. F. C. Annett, Royal Institution, Liverpool	213	None	Resident 1*l.* 1*s.* Non-Res. 10*s.* 6*d.*	Transactions, annually.
Liverpool Geographical Society, 1891	Liv'pool Geog. Soc.	G. A. Craig, F.R.G.S., 6A The Temple, Dale Street, Liverpool	320	None	1*l.* 1*s.*	Uncertain.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc.	Royal Institution. H. C. Beasley	54	None	1*l.* 1*s.*	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. John Rutherford, LL.B., Wason Chambers, 4 Harrington Street, Liverpool	271	10*s.* 6*d.*	1*l.* 1*s.*	Proceedings, annually.
Liverpool Microscopical Society, 1869	Liv'pool Mic. Soc.	Royal Institution. Wm. Oelrichs, Sunnyside, Oxton, Cheshire	122	10*s.* 6*d.*	10*s.* 6*d.*	Journal, generally annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Thomas J. Blanche and W. Sutherland, Malton, Yorkshire	90	None	5*s.*	Report, every two years.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Masonic Rooms, Ramsey, Isle of Man	134	2*s.* 6*d.*	Gentlemen 6*s.* Ladies 3*s.*	Yn Lioar Manninagh, quarterly

1885		Street, Manchester				
Manchester Geological Society, 1838	Manch. Geol. Soc.	Mark Stirrup, F.G.S., 36 George Street, Manchester	216	None	1*l.*	Transactions, eight or nine parts per annum.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	25 Booth Street, Manchester. Francis E. M. Beardsall and G. H. Pownall	185	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick.	320	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.
Midland Union of Natural History Societies, 1877	Mid. Union	Dr. T. Stacey Wilson, Wyddrington, Edgbaston, Birmingham, and W. Wickham King, Pedmore House, Stourbridge	15 Societies	—	3*d.* per Member	'Midland Naturalist,' monthly.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	670	None	21*s.* and 42*s.*	Transactions, about every two months.
North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	383	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc.	The Museum, Guildhall Road, Northampton. H. N. Dixon	200	None	10*s.*	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Nottingham Institute, 9 Shakespeare Street. F. R. Jackson	153	None	5*s.*	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	385	5*s.*	7*s.* 6*d.*	Report, annually.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	G. F. Tregelles, 3 Market Place, Penzance	92	None	10*s.* 6*d.*	Report and Transactions, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	294	2*s.* 6*d.*	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, 20 King Street South, Rochdale	244	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Union Street, Rochester	162	None	3*s.* 6*d.*, 5*s.*, and 10*s.*	'Rochester Naturalist,' quarterly.
Somersetshire Archæological and Natural History Society, 1849	Som'setsh. A. N. H. Soc.	The Castle, Taunton. F. T. Elworthy	554	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc.	W. H. Finlay, Royal Observatory, Cape Town	75	None	2*l.*	Transactions, annually.
South London Microscopical and Natural History Club, 1871	S. London M. N. H. C.	Brixton Hall, Acre Lane, Brixton. H. Groves	110	None	10*s.*	Report, annually.
Tyneside Geographical Society, 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. G. E. T. Smithson	1,200	None	10*s.*	Journal, half yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	W. G. Fretton, F.S.A., Hearsall Terrace, Chapel Fields, Coventry	80	2*s.* 6*d.*	5*s.*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	219	10*s.*	10*s.*	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	James W. Davis, F.G.S., Chevinedge, Halifax	250	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, F.L.S., Sunny Bank, Leeds; Rev. E. P. Knubley, M.A., Staveley Rectory, Leeds; and Edgar R. Waite, F.L.S., The Museum, Leeds	462 and 2,488 Associates	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc.	Museum, York. T. S. Noble, F.G.S.	350	None	2*l.*	Report, annually.

Index of the more important Papers, and especially those referring to Local Scientific Investigations, published by the above-named Societies during the year ending June 1, 1892.

*** This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—Mathematical and Physical Science.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Abbe, Prof. C.	The Modern Weather Bureau	S. African Phil. Soc.	*Trans.*	VI.	17	1891
Andson, Rev. W.	Observations on the Temperature of the Galloway Dee	Dum. Gal. N. H. A. Soc.	„	7	6	„
„ „	Meteorology of Dumfries for 1890	„ „ „	„	„	51	„
Barr, Prof. A.	The Optical Lantern in Class-room Work	Glasgow Phil. Soc.	*Proc.*	XXII.	287	„
Bayard, F. C.	Report of the Meteorological Sub-Committee for 1890	Croydon M. N. H. C.	*Proc. and Trans.*	For 1890-1	285	„
Binns, G. J.	On Lightning in New Zealand Mines	N. England Inst.	*Trans.*	3	415	1892
Brown, M. Walton	Report on the Experiments with Explosives at Elemore, Haswell, and South Hetton Collieries	Fed. Inst. Min. Eng.	„	2	398	1891
„ „	Barometer and Thermometer Readings, 1890	„ „	„	3	556	1892
Buchan, Dr. A.	The Meteorological Results of the 'Challenger' Expedition in relation to Physical Geography	Glasgow Phil. Soc.	*Proc.*	XXII.	305	1891
Buchan, W. P.	A Problem in Ventilation by Heat	„ „	„	„	31	„
Burder, Dr. G. F.	Rainfall at Clifton, 1890	Bristol Nat. Soc.	„	VI.	287	„
„ „	The Frosts of recent Years	„ „	„	„	294	„
Clark, J. E.	Fifty Years of York Weather	Yorks. Phil. Soc.	*Report*	For 1892	26	1892
„ „	On Meteorological Records made at York during May 1891	„ „	„	„	29	„
Clayden, A. W.	The Application of Photography to Meteorology	Herts. N. H. Soc.	*Trans.*	VI.	162	1891
Crouch, W.	Physical Conditions of the Sea	Croydon M. N. H. C.	*Proc. and Trans.*	For 1890-1	251	„
Cushing, T.	Wandle Temperatures	„ „ „	„ „	„	316	„
Dixon, H. N.	Phenological Observations	N'ton. N. H. Soc.	*Journal*	VI.	254	„
Drummond, D., and Hume, G. H.	Report on the Effects produced by the Explosives Roburite and Tonite	Fed. Inst. Min. Eng.	*Trans.*	2	385	„
Dudgeon, P.	Meteorological Notes on the Winter of 1890–91	Dum. Gal. N. H. A. Soc.	„	7	129	„
Evans, F. G.	Meteorology and kindred Phenomena of 1890	Cardiff Nat. Soc.	„	XXII.	75	„
Hewitt, C. E. B.	Meteorological Report	Marlb. Coll. N. H. Soc.	*Report*	XI.	153	1892

Hopkinson, J.	Meteorological Observations taken at the Grange, St. Albans, during the year 1890	Herts. N. H. Soc.	*Trans.*	VI.	179	,,
,, ,,	Report on the Rainfall in Hertfordshire in 1890	,, ,,	,,	,,	187	,,
,, ,,	Climatological Observations taken in Hertfordshire in 1890	,, ,,	,,	,,		
Lang, W., jun.	Giphantie: a remarkable Forecast of Photography in 1760	Glasgow Phil. Soc.	*Proc.*	XXII.	284	,,
McLandsborough, J., & A. E. Preston	Meteorology of Bradford for 1888, 1889, and 1890	Yorks. Nat. Union	*Trans.*	16	—	,,
,, ,,	Meteorological Statistics	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	131	1892
Maclean, M.	Some Electrical Properties of Flames	Glasgow Phil. Soc.	,,	XXII.	255	1891
Markham, C. A.	Meteorological Reports	N'ton. N. H. Soc.	*Journal*	VI.	187,219, 257, 286	,,
Mawley, E.	The Percolation of Rain through comparatively Light and through comparatively Heavy Soil	Herts. N. H. Soc.	*Trans.*	,,	175	,,
Moore, A. W.	The Climate of the Isle of Man	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	145	1892
Murray, J. E.	Some Experiments on the Viscosity of Air	Glasgow Phil. Soc.	*Proc.*	XXII.	199	1891
Nevins, A. E.	Meteorological Report	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	—	1892
Reynolds, R.	Study of intense Rainfall at Leeds, July 19, 1891	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	94	,,
Rintoul, D.	Observations of Temperature at Clifton, 1890	Bristol Nat. Soc.	,,	VI.	290	1891
Stratton, T. H. M.	An Inquiry into the Cause of the Two Seaham Explosions, 1871 and 1880, and the Pochin Explosion, 1884	N. Eng. Inst.	*Trans.*	3	385	1892
Watts, W.	Thermometrical Observations of Atmospheric Air and Water at Piethorn and Denshaw	Manch. Geol. Soc.	,,	XXI.	503	,,
Wells, J. G.	The Weather of 1890	Burt. N. H. Arch. Soc.	*Report*	For 1890-1	15	1891
Whytehead, H. E.	Photographic Report	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	—	1892
Report of the Committee	An Investigation whether the Fumes produced from the use of Roburite and Tonite in Coal-mines are injurious to Health	Fed. Inst. Min. Eng.	*Trans.*	2	368	1891

Section B.—CHEMISTRY.

Ashworth, J., and Prof. F. Clowes	The Detection of Fire-damp	Fed. Inst. Min. Eng.	*Trans.*	2	352	1891
Bedson, Dr. P. P.	Reports on the Chemical Examination of the Fumes from the Explosives Roburite, Tonite, and Gunpowder	,, ,,	,,	,,	369,388	,,

Section B.—CHEMISTRY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Bedson, Dr. P. P., & W. McConnell	Notes on the Gases enclosed in Coal and Coal Dust	N. Eng. Inst.	*Trans.*	3	307	1892
Brierley, J.	Hampshire Fuller's Earth	Hants. F. C.	*Proc.*	2	84	1891
Chicken, L. W.	Experiments with Explosives	N. Eng. Inst.	*Trans.*	3	88	1892
Dampier, H. L.	Rural Chemistry	Rochester N. C.	*Roch. Naturalist*	II.	75	,,
Dittmar, Prof. W., & J. B. Henderson	On the Gravimetric Composition of Water	Glasgow Phil. Soc.	*Proc.*	XXII.	33	1891
Dixon, Prof. H. B.	The Rate of Explosions in Gases	Fed. Inst. Min. Eng.	*Trans.*	3	312	1892
Ferguson, Prof. J.	Remarks on the First Edition of the Chemical Writings of Democritus and Synesius: Part II.	Glasgow Phil. Soc.	*Proc.*	XXII.	295	1891
Hall, H.	Coal Dust	Fed. Inst. Min. Eng.	*Trans.*	2	415	,,
Mayer, Jno.	Memoir of the late Alexander Whitelaw	Glasgow Phil. Soc.	*Proc.*	XXII.	311	,,
Murday, T. J.	Fire-damp Detector	N. Eng. Inst.	*Trans.*	2	469	,,
Nowers, J. E., and J. G. Wells	Notes on a Salt Marsh at Branston	Burt. N. H. Arch. Soc.	,,	II.	50	1892
Orsman, W. J.	Notes on the Products and Temperature of Detonation of some High Explosives	N. Eng. Inst.	,,	3	91	,,

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Armstrong, J. N.	The Antiquity of Man	Rochester N. C.	*Roch. Naturalist*	II.	49	1891
Barker, F.	The Fauld Gypsum Mines	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	—	1892
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Beasley, H. C.	The Base of the Keuper in the Northern part of Wirral	Liv'pool Geol. Soc.	*Proc.*	VI.	248	1891
Bedford, J. E.	Evidence of Glacial Action near Leeds	Yorks. Geol. Poly. Soc.	,,	XII.	69	1892
Bell, D.	Notes on remarkable Glacial Mounds in Glen Fruin, Dumbartonshire	Glasgow Geol. Soc.	,,	IX.	—	,,
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Bennie, Jas.	Scenes and Sections in Thornton Quarries in 1868	Glasgow Geol. Soc.	,,	IX.	—	1892
olton, H.	On the Finding of Marine Shells in the Boulder Clay of Bacup, Lancashire	Manch. Geol. Soc.	*Trans.*	XXI.	374	,,

Bonney, Prof. T. G.	The Former Glaciation of Arran					
Brodie, Rev. P. B.	On certain Arachnids and Myriapods in the American and British Carboniferous Rocks, and their occasional Occurrence in other Newer Formations	Warw. N. A. F. C.	*Proc.*	36	29	„
Brown, H. T.	Notes on a Summer Tour in Norway	Burt. N. H. Arch. Soc.	*Trans.*	II.	70	„
Brownridge, C.	Our Walls and Pavements	Leeds Geol. Assoc.	„	VI.	33	1891
Cadell, H. M.	Plant Remains in Olivine Basalt	Edinb. Geol. Soc.	„	„	191	1892
Carter, W. L.	The Geological History of England	Leeds Geol. Assoc.	„	„	59	1891
„ „	The Life History of a Volcano	„ „	„	„	65	„
„ „	Field Excursions	„ „	„	„	79	„
Chadwick, S.	The Yorkshire Boulder Committee and its Fourth Year's Work	Yorks. Nat. Union	*The Naturalist*	For 1892	155	1892
Cheetham, W.	A Geological Tour through Durham into Cumberland	Leeds Geol. Assoc.	*Trans.*	VI.	12	1891
Clark, W. F., and H. W. Hughes	A General Description of the South Staffordshire Coalfield South of the Bentley Fault, and the Methods of working the Ten-Yard or Thick Coal	Fed. Inst. Min. Eng.	„	3	25	1892
Clay, W. G.	Note on Mr. Dickson's paper on Moraines and Glacial Streams in the Valley of the Rhone and near Grindelwald	Liv'pool Geol. Soc.	*Proc.*	VI.	271	„
Coates, H. and P. Macnair.	The Rocks of Highland Perthshire: their Origin, Plication, and Denudation	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	221	1891
Cole, Rev. E. M.	The Erosion of the Yorkshire Coast	Yorks. Nat. Union	*The Naturalist*	For 1892	103	1892
Colenutt, G. W.	The Geology of the Isle of Wight	Hants. F. C.	*Proc.*	2	20	1891
Collins, J. H.	Notes on certain Illustrations of Sub-aerial Denudation due to Changes of Temperature	Cornw. R. Geol. Soc.	*Trans.*	XI.	375	1892
Cox, S. H.	The Coalfields of Australasia	Fed. Inst. Min. Eng.	„	2	321	1891
Crick, W. D., and C. D. Sherborn	On some Liassic Foraminifera from Northamptonshire	N'ton. N. H. Soc.	*Journal*	VI.	208	„
Dairon, J.	The Lower Carboniferous System in Dumfriesshire	Dum. Gal. N. H. A. Soc.	*Trans.*	7	103	„
Davis, J. W.	The Fossil Fishes of the Chalk	Leeds Geol. Assoc.	„	VI.	9	„
„ „	Bibliography, 1889–1890	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	119	1892
Dawkins, Prof. W. Boyd	The Channel Tunnel	Manch. Geog. Soc.	*Journal*	7	81	„
„ „	On the further Discovery of Coal at Dover and its Bearing on the Coal Question	Manch. Geol. Soc.	*Trans.*	XXI.	456	„
De Rance, C. E.	Further Notes on Triassic Borings	„ „	„	„	478	„
„ „	On the Underground Waters of Lincolnshire	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	22	„

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Dickson, E.	Observations on Moraines and Glacial Streams in the Valley of the Rhone and near Grindelwald	Liv'pool Geol. Soc.	*Proc.*	VI.	259	1891
Dougall, Prof. Jno.	The Leaf Caves of Mull	Glasgow Geol. Soc.	„	IX.	—	1892
Dow, R.	Tertiary Dykes of the Lower Tay Valley and District around Perth	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	226	1891
Eve, A. S.	Coombs and Lynchets	Marlb. Coll. N. H. Soc.	*Report*	XI.	89	1892
Fitzpatrick, J. J.	Report on the Field Meeting of the Society at a Section of the Coal Measures between Garswood and St. Helens	Liv'pool Geol. Soc.	*Proc.*	VI.	289	„
Forsyth, D.	The Geology of Cassphairn	Glasgow Geol. Soc.	„	IX.	—	„
French, J., W. H. Dalton, and H. W. Monckton	On the Occurrence of Westleton Beds in part of North-West Essex	Essex F. C.	*Essex Naturalist*	V.	210	1891
Geikie, Prof. J.	The supposed Causes of the Glacial Period	Edinb. Geol. Soc.	*Trans.*	VI.	209	1892
Goodchild, J. G.	Notes on some of the Limestones of Cumberland and Westmorland	Cumb. West Assoc.	„	XVI.	125	1891
Goodman, C. H.	Notes on the Geology of the Isle of Purbeck	Croydon M. N. H. C.	*Proc. and Trans.*	For1890–91	270	„
Gresley, W. S.	A Typical Section, taken in detail, of the 'Main Coal' of the Moira or Western Division of the Leicestershire and South Derbyshire Coalfield	Manch. Geol. Soc.	*Trans.*	XXI.	520	1892
Hardcastle, C. D.	Agates	Leeds Geol. Assoc.	„	VI.	43	1891
Harker, A.	Bibliography, Geology and Palæontology, 1890	Yorks. Nat. Union	*The Naturalist*	For 1891	313	„
„ „	Some North Country Quartzites	„ „	„ „	For 1892	73	1892
Hawkesworth, E.	From Kettleness to Saltburn	Leeds Geol. Assoc.	*Trans.*	VI.	55	1891
Heddle, Prof. M. F.	On Pectolite and Okenite from new Localities; the former with new Appearances	Glasgow Geol. Soc.	*Proc.*	IX.	—	1892
Hick, T.	On the present state of our Knowledge of Yorkshire *Calamitæ*	Yorks. Geol. Poly. Soc.	„	XII.	1	„
Hinde, Dr. G. J.	Discovery of Chert containing Radiolaria, &c., in the Palæozoic Rocks	Croydon M. N. H. C.	*Proc. and Trans.*	For1890–91	253	1891
Hobson, B.	On the Igneous Rocks of the South of the Island, and Sections through Scarlet Point, with Plans	I. of Man N. H. A, Soc.	*Yn Lioar Manninagh*	I.	337	1892

„ „ .	The Mode of Deposition and Properties of the Carboniferous Strata of Leeds and its immediate Suburbs	Yorks. Geol. Poly. Soc. .	*Proc.* . . .	XII.	9	1892
Holland, P., and E. Dickson	Examination of Glacial Waters and Deposits from the Rhone Valley and near Grindelwald, and of Glacial Waters from near Chamounix	Liv'pool Geol. Soc. .	„ . . .	VI.	322	„
Holmes, T. V. .	Geology of Club's Voyage from Maldon to Chelmsford	Essex F. C. . . .	*Essex Naturalist* .	V.	197	1891
Holmes, W. M. .	Glauconite Casts from Godstone Firestone .	Croydon M. N. H. C. .	*Proc. and Trans.* .	For 1890-91	272	„
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Hopkinson, J. .	Water and Water-supply, with special reference to the Supply of London from the Chalk of Hertfordshire	Herts. N. H. Soc. . .	„ „ .	VI.	129	1891
Horne, J. . .	Obituary Notice of Dr. J. Croll . . .	Edinb. Geol. Soc. . .	„ . . .	„	171	1892
Hoskold, H. D. .	Notes upon the Mines in the Argentine Republic, South America	N. Eng. Inst. . . .	*Trans. Fed. Inst.* .	3	418	„
Hughes, W. R. .	Note on the Severn Bore	Birm. N. H. M. Soc. .	*Mid. Naturalist* .	XV.	79	„
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Kidston, R. . .	Notes on some Fossil Plants from the Lancashire Coal Measures	Manch. Geol. Soc. . .	*Trans.* . . .	XXI.	401	„
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Kinnear, W. T. .	*Homocanthus Borealis*	„ „ . .	„ . . .	„	205	„
Lapworth, Prof. C.	Sketch of the Geology of the Birmingham District	Fed. Inst. Min. Eng. .	„ . . .	3	10	„
Leighton, T. .	On recent Discussions relating to the Geology of the South-East of England	S. London M. N. H. C. .	*Report* . . .	„	9	1891
Lewkowitsch, Dr. J.	The Physical Properties of Ice and Glaciers .	Leeds Geol. Assoc. . .	*Trans.* . . .	VI.	21	„
Liddell, J. M. .	The Witwatersrandt Goldfields	N. Eng. Inst. . . .	„ . . .	3	447	1892
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Marr, J. E. . .	The Backbone of England	Leeds Geol. Assoc. .	*Trans.* . . .	VI.	51	1891
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Monckton, H. W. .	Notes on the Glacial Formation near Chelmsford	Essex F. C. . . .	*Essex Naturalist* .	V.	191	1891

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Morton, G. H.	Faulted Areas in the Country round Liverpool	Liv'pool Geol. Soc.	*Proc.*	„	294	„
„ „	List of Papers on Local Geology since 1881	„ „	„	„	297	„
Murdoch, J. B.	Notes on the Culbin Sands, Morayshire	Glasgow Geol. Soc.	„	IX.	—	„
Nash, H. B.	The Unworked Coal Seams of Barnsley and District	Barnsley Nat. & Sci. Soc.	*Pamphlet*	„	—	„
Newton, E. T.	Note on the Occurrence of *Ammonites Jurensis* in the Ironstone of the Northampton Sands in the Neighbourhood of Northampton	N'ton. N. H. Soc.	*Journal*	VI.	266	1891
Paul, J. D.	Recent Geological Notes	Leicester Lit. Phil. Soc.	*Trans.*	II.	405	„
Pearson, H. W.	Some of the Water-bearing Strata, and Wells sunk in same	Bristol Nat. Soc.	*Proc.*	VI.	327	„
Pike, E. R.	Mining in Perak, Straits Settlements	Cornw. Min. Assoc. Inst.	*Trans.*	3	—	1892
Platnauer, H. M.	Notes on Two Borings	Yorks. Phil. Soc.	*Report*	For 1892	51	„
Postlethwaite, C.	The Cleaved Ashes and Breccias of the Volcanic Series of Borrowdale	Cumb. West. Assoc.	*Trans.*	XVI.	41	1891
Praeger, R. Ll.	On the Skull of an Irish Elk lately found at Belfast	Belfast Nat. F. C.	*Report and Proc.*	III.	416	1892
Reade, T. M.	The Trias of the Vale of Clwyd	Liv'pool Geol. Soc.	*Proc.*	VI.	278	„
„ „	Notes on a Section of the Trias and Boulder Clay in Chapel Street, Liverpool	„ „	„	„	316	„
„ „	A further Note on the Decomposed Boulder and underlying Red Sandstone in the Chapel Street Section, Liverpool	„ „	„	„	333	„
„ „	Stalagmites of Sand	Yorks. Nat. Union	*The Naturalist*	For 1891	179	1891
„ „	Sand Sculpture	„ „	„ „	For 1892	149	1892
Reid, A. S.	Sandpipes	E. Kent N. H. Soc.	*S. E. Naturalist*	I.	43	1891
„ „	Concretions and Concretionary Actions	„ „	„ „	„	48	„
Reid, Jas.	Bones and Teeth found in Valley Drift of the River Stour	„ „	„ „	„	51	„
Richardson, C.	Landslips	Bristol Nat. Soc.	*Proc.*	VI.	301	„
Richardson, R.	Scottish Earthquakes of the present Century	Edinb. Geol. Soc.	*Trans.*	„	194	1892
Ricketts, Dr. C.	Some Phenomena which occurred during the Glacial Epoch	Liv'pool Geol. Soc.	*Proc.*	„	225	1891
Rosenbusch, Prof. H.	Note on the Metamorphosed Skiddaw Slates	Yorks. Nat. Union	*The Naturalist*	For 1892	119	1892
Seeley, Prof. H. G.	Some Scientific Results of a Mission to South Africa	S. African Phil. Soc.	*Trans.*	VI.	1	1891

Shore, T. W.	The Streams of Hampshire	Hants. F. C.	*Proc.*	2	33	„
Smith, John.	'Torr's Warren,' Wigtonshire	Glasgow Geol. Soc.	„	IX.	—	1892
Sopwith, A.	The Northern Part of the South Staffordshire Coalfield	Fed. Inst. Min. Eng.	*Trans.*	3	50	„
Sowerbutts, E.	Delegates' Report, British Association Meeting, Cardiff	Manch. Geog. Soc.	*Journal*	7	—	„
Spencer, Jas.	The Common Fossil Plants of the Coal Measures	Leeds Geol. Assoc.	„	VI.	24	1891
„ „	On the Affinity of Dadoxylon to Cordaites	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	95	1892
Stirrup, M.	Earth Sculpture as illustrated in the Gorges of the Tarn and at Montpellier-le-Vieux, Southern France	Manch. Geog. Soc.	*Journal*	6	364	1891
„ „	Delegate's Report, British Association Meeting, Cardiff	Manch. Geol. Soc.	*Trans.*	XXI.	352	„
Swanston, W.	A Fossiliferous Ironstone Nodule	Belfast Nat. F. C.	*Report and Proc.*	III.	401	1892
Tate, T.	A Geological Episode as recorded in the Ingleton Granite	Leeds Geol. Assoc.	*Trans.*	VI.	54	1891
„	The Yorkshire Boulder Committee and its Fifth Year's Work	Yorks. Nat. Union	*The Naturalist*	For 1892	159	1892
Thomas, T. H.	A Visit to the Volcanoes of South Italy	Cardiff Nat. Soc.	*Trans.*	XXIII.	10	„
Thompson, Beeby.	The Oolitic Rocks at Stowe-Nine-Churches	N'ton. N. H. Soc.	*Journa*	VI.	295	1891
Tute, Rev. J. S.	On a Permian Conglomerate Bed at Markington	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	72	1892
Ussher, W. A. E.	Palæozoic Strata beneath Secondary Rocks, with special reference to the Prospect of obtaining Coal South of the Mendips	Som'setsh. A. N. H. Soc.	„	XXXVI.	82	1891
Vine, G. R.	Notes on some new or but little-known Eocene Polyzoa from Localities	Yorks. Geol. Poly. Soc.	„	XII.	52	1892
„ „	British Palæozoic Ctenostomatous Polyzoa	„ „ „	„	„	74	„
Walker, G. B.	Notes on the Coalfields of New South Wales	Fed. Inst. Min. Eng.	*Trans.*	2	268	1891
Waller, T. H.	Note on some Ores from the Barrier Ranges, New South Wales	Birm. N. H. M. Soc.	*Mid. Naturalist*	XIV.	256	„
„ „	A Week in North Wales	„ „ „	„ „	XV.	109	1892
Wardle, T.	The Geology of the District round Worksop	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	—	„
Whitaker, W.	Essex Well Sections: Part III.	Essex F. C.	*Essex Naturalist*	VI.	48	„
White, Jas.	A Glimpse of the Irish Highlands	Glasgow Geol. Soc.	*Proc.*	IX.	—	„
Wild, G.	On the Lower Coal Measures of Lancashire	Manch. Geol. Soc.	*Trans.*	XXI.	364	1891
Williamson, Prof. W. C.	On his earlier Palæontological Works	„ „	„	„	488	1892
Winwood, Rev. H. H., and E. Wilson	Notes on the Life and Work of Charles Moore, F.G.S., with a List of the Fossil Types in the Bath Museum	Bath N. H. A. F. C.	*Proc.*	VII.	232	„

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Woodward, A. S.	The Hybodont and Cestraciont Sharks of the Cretaceous Period	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	62	1892
Woodward, H. B.	On the Geology of Crewkerne	Som'setsh. A. N. H. Soc.	„	XXXVII.	60	„
Worth, R. N.	The Succession of the Plymouth Devonians	Cornw. R. Geol. Soc.	*Trans.*	XI.	381	„
Young, Prof. J.	Notice of the late Sir A. C. Ramsay	Glasgow Geol. Soc.	*Proc.*	IX.	—	„
Young, R.	Geology of Main Drainage Works	Belfast N. H. Phil. Soc.	„	For 1891–2	89	„

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Addison, Rev. F.	Some Vernacular Names of Plants	Yorks. Nat. Union	*The Naturalist*	For 1892	111	1892
Alpin, O. V.	Observations on the White Wagtail	„ „	„ „	For 1891	349	1891
Arlidge, Dr. J. T.	The British Association Meeting at Cardiff, 1891	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	13	1892
Bailey, Rev. G.	The Tenants of a Fossil Echinus	Croydon M. N. H. C.	*Proc. and Trans.*	For 1890–1	253	1891
Barnes, R.	Four new Yorkshire Mosses	Yorks. Nat. Union	*The Naturalist*	For 1892	151	1892
Batten, E. C.	The Forest Trees of Somerset	Som'setsh. A. N. H. Soc.	*Proc.*	XXXVI.	175	1891
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Bennett, A.	Notes on the Flora of Dumfriesshire	Dum. Gal. N. H. A. Soc.	*Trans.*	7	84	1891
Blomefield, Rev. L.	Distribution and Movements of British Animals and Plants	Bath N. H. A. F. C.	*Proc.*	VII.	—	1892
Bolam, G.	Occurrence of the Snow Goose in Northumberland during the Winter of 1890–91	Yorks. Nat. Union	*The Naturalist*	For 1892	1	„
Bouskell, F., and C. B. Headly	Notes on the Distribution and Variation of the Leicestershire Macro-Lepidoptera	Leicester Lit. Phil. Soc.	*Trans.*	II.	365	1891
Brett, Dr. A. T.	Report on Diseases of Plants in Hertfordshire in 1890	Herts. N. H. Soc.	„	VI.	191	„
Brown, H. T.	Some Varieties of Huskless Barley from Thibet	Burt. N. H. Arch. Soc.	„	II.	30	1892
Bucknall, C.	British Fungi: Part XIII.	Bristol Nat. Soc.	*Proc.*	VI.	274	1891
Burgess, E. W.	The Foraminifera of Hammerfest, Norway	Birm. N. H. M. Soc.	*Mid. Naturalist*	XIV.	153	„
Burton, W.	Foraminifera	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	—	1892
Cambridge, Rev. O. P.	On new and rare Spiders found in 1889–90	Dorset N. H. A. F. C.	*Proc.*	XII.	80	1891
„ „	New and rare Dorset Land Shells	„ „	„	„	99	„
„ „	On Rooks planting Acorns	„ „	„	„	132	„

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Clifton, Lord	On Mr. Fielding's Paper on Kentish Birds	Roohester N. C.	*Roch. Naturalist*	II.	65	1892
Cole, W., and H. Laver	Spotted Eagles at Elmstead and Leigh, an Addition to the Essex Fauna	Essex F. C.	*Essex Naturalist*	V.	218	1891
Cooke, Dr. M. C.	Plant Diseases and Fungi	,, ,,	,, ,,	VI.	17	1892
Cordeaux, J.	Bird Notes from North Lincolnshire, March, April, May, 1891	Yorks. Nat. Union	*The Naturalist*	For 1891	209	1891
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,, ,,	Ornithological Notes from the Humber District, in the Autumn of 1891	,, ,,	,, ,,	,,	355	,,
Cox, S. B.	Shells and Shell Collecting	E. Kent N. H. Soc.	*S. E. Naturalist*	I.	49	,,
Crellin, J. C.	Address as Retiring President	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	,,	270	,,
Crouch, W.	On a Female Specimen of the common Rorqual captured near Burnham, Essex	Essex F. C.	*Essex Naturalist*	V.	124	,,
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,, ,,	Notes of Two Days' Trawling and Dredging on the River Crouch, Oct. 10 and 15, 1891	,, ,,	,, ,,	VI.	81	1892
Daltry, Rev. T. W.	Entomological Report	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	74	,,
Davidson, Dr. A.	British Plants in Southern California	Dum. Gal. N. H. A. Soc.	*Trans.*	7	112	1891
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Dixon, H. N.	Recent Additions to the Northamptonshire Moss Flora	N'ton. N. H. Soc.	*Journal*	VI.	246	1891
Dowker, G.	The History of an Ear of Wheat	E. Kent N. H. Soc.	*S. E. Naturalist*	I.	39	,,
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Druce, G. C.	The Flora of Northamptonshire	N'ton. N. H. Soc.	*Journal*	VI.	172, 249	,,
Duncan, W.	Cassava	Bristol Nat. Soc.	*Proc.*	,,	418	,,

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Edwards, W.	Entomological Notes.	N'ton. N. H. Soc.	*Journal*	VI.	233	,,
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Fingland, J.	The Genus *Rosa* in Nithsdale	Dum. Gal. N. H. A. Soc.	*Trans.*	7	106	,,
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Mayou, Mrs. R.	Cats: their Use and Abuse	Rochester N. C.	*Roch. Naturalist*	„	81	„
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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Ashworth, Jas.	Notes on recent Accidents from Blasting in Coal Mines	Manch. Geol. Soc.	*Trans.*	XXI.	339	1891
Bastable, Prof.	Banking Reserves and Currency Reform	Stat. Soc. Ireland	*Journal*	IX.	562	„
Bonar, Dr. Jas.	The Relations of Thomas Carlyle to Political Economy	Glasgow Phil. Soc.	*Proc.*	XXII.	139	„
Buchan, W. P.	The Progress of Sanitation with special reference to the Sanitary Condition of Glasgow Public Schools	„ „	„	„	217	„
Courtney, L. H.	Proportional Representation	Belfast N. H. Phil. Soc.	„	For 1891-92	21	1892
Daly, E. D.	Our Industrial and Reformatory School Systems in relation to the Poor	Stat. Soc. Ireland	*Journal*	IX.	523	1891
Grimshaw, Dr. T. W.	Irish Progress during the last Ten Years, 1881–90	„ „	„	„	571	„
Grundy, Jas.	On Accidents in Coal Mines	Manch. Geol. Soc.	*Trans.*	XXI.	439	1892
Kelly, R. J.	The Congested Districts	Stat. Soc. Ireland	*Journal*	IX.	495	1891
Mager, A. W.	The Children's Home on the Moors at Edgworth	Manch. Geog. Soc.	„	7	137	1892
Maguire, J.	The Registration of Assurances Bill	Stat. Soc. Ireland	„	IX.	516	1891
Moore, F.	Some Notes upon Light Railways and Tramway Guarantees in Ireland under the Tramways and Public Companies Act, 1883, 46 & 47 Vict. c. 43, and Suggestions for a different and improved System of Guarantee	„ „	„	„	512	„
Munro, Prof. J. E. C.	On Wages and Hours of Working in the Coal Industry in France, Germany, and England	Manch. Stat. Soc.	*Trans.*	For 1891-92	1	1892
Murphy, J. J.	The Case for Bimetallism	Stat. Soc. Ireland	*Journal*	IX.	543	1891
O'Gorman, D. A.	Recent Trade Progress and Competition in India	Manch. Geog. Soc.	„	7	230	1892
Pankhurst, Dr. R. M.	On the Companies Act, 1862, and subsequent Acts, and suggested Amendments	Manch. Stat. Soc.	*Trans.*	For 1891-92	77	„
Paton, Jas.	An Art Museum: its Structure and Requirements	Glasgow Phil. Soc.	*Proc.*	XXII.	128	1891

Pownall, G. H.	On Bank Reserves, the Central Stock of Gold, and One Pound Notes	Manch. Stat. Soc.	*Trans.*	For 1891-92	16	1892
Smith, J. B.	On Colliery Depreciation	Chesterf. Mid. Count. Inst.	„	2	211	1891
Sutcliffe, John	On the Financial Crises of 1866 and 1890	Manch. Stat. Soc.	„	For 1891-92	99	1892
Tonge, Jas	The Future of Coal Mining	Manch. Geol. Soc.	„	XXI.	329	1891
Tupper, C. L.	The recent Progress of Indian Agriculture	Manch. Geog. Soc.	*Journal*	7	201	1892
Vambery, Prof. A.	British Trade in Central Asia	„ „	„	„	87	„

Section G.—Mechanical Science.

Bigge, D Selby	The Practical Transmission of Power by means of Electricity, and its Application to Mining Operations	N. Eng. Inst.	*Trans.*	3	278	1892
Brown, M. Walton	The Lee Alarm Water Gauge	„	„	„	128	1891
„ „	The Roberts Shot-firing Lamp	„	„	„	129	„
„ „	The Rateau Ventilator	„	„	„	410	1892
„ „	The König Differential Water Gauge	„	„	„	452	—
Capell, Rev. G. M.	Notes on Fan Gauges in connection with Fan testing and the Adaptation of Fans to Mines; and Comparison of Fan and Furnace at Silverhill Colliery	Chesterf. Mid. Count. Inst.	„	III.	196	1891
Cochrane, W.	On a Duplex Arrangement of Centrifugal Ventilating Machines	N. Eng. Inst.	„	2	483	„
Cockson, C.	Notes on Mining Explosives	Manch. Geol. Soc.	„	XXI.	235	„
Deacon, M.	Notes on Alfreton Colliery	Chesterf. Mid. Count. Inst.	„	III.	158	„
„	Notes upon a small Electric Pumping Plant	„ „ „	„	„	191	„
Foggin, W.	Locked Coil Wire Ropes	Fed. Inst. Min. Eng.	„	2	261	„
Griffith, N. R.	Notes on the Sinking at Lens Collieries, No. 10 Pit, by the Poetch System	„ „	„	„	441	„
Gulbransen, P. F.	Difficulties about Pendulums	Belfast N. H. Phil. Soc.	*Proc.*	For 1891-92	87	1892
Guthrie, J. K.	Pumping Appliances at Eltringham Colliery	N. Eng. Inst.	*Trans.*	2	457	1891
Hendy, J. C. B.	The Stanton Ironworks Company's Collieries	Chesterf. Mid. Count. Inst.	„	„	531	„
Holman, F.	An Old Mine Pump	Penz. N. H. A. Soc.	*Report and Trans.*	III.	—	1892
Longden, J. A.	Presidential Address	Chesterf. Mid. Count. Inst.	*Trans.*	2	513	1891
Macassey, L. L.	The proposed Channel Tunnel	Belfast N. H. Phil. Soc.	*Proc.*	For 1891-92	44	1892

Section G.—MECHANICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
McLaren, John	The Economical Use of Steam in Colliery Engines	Fed. Inst. Min. Eng.	*Trans.*	2	344	1891
Marsh, F. S.	Germans (Fuzes)	Chesterf. Mid. Count. Inst.	,,	,,	100	,,
Mawson, R. B.	On an Apparatus for laying Coal Dust in Mines	Manch. Geol. Soc.	,,	XXI.	249	,,
Orsman, W.	On the Detonation of High Explosives	,, ,,	,,	,,	445	1892
Palmer, H.	Notes on an Electric Transmission Plant at East Howle Colliery	N. Eng. Inst.	,,	3	271	,,
Speakman, J. J.	The Speakman Water Cartridge	Fed. Inst. Min. Eng.	,,	,,	359	,,
Sutcliffe, R.	A Sinking Machine and a new system of sinking pits	Manch. Geol. Soc.	,,	XXI.	263	1891
,,	The practical working of Coal-cutting Machines	,, ,,	,,	,,	563	1892
Swallow, R. T.	Description of a Method of removing Deposits from the Inside of Rising Main Pipes in Shafts.	N. Eng. Inst.	,,	3	113	,,
Wallis, T. M. W.	The Low-tension System of Shot-firing	Chesterf. Mid. Count. Inst.	,,	2	553	1891
Workman, W.	Ventilation with Heating	Belfast N. H. Phil. Soc.	*Proc.*	For 1891-92	72	1892
Yates, J.	An Electrical Safety Apparatus for Cages	Fed. Inst. Min. Eng.	*Trans.*	2	362	1891

Section H.—ANTHROPOLOGY.

Annandale, Dr. C.	The Anglo-Saxon Poem of Beowulf in the Light of present Studies	Glasgow Phil. Soc.	*Proc.*	XXII.	240	1891
Bennett, A. H.	An English Village in the Thirteenth Century	Leicester Lit. Phil. Soc.	*Trans.*	II.	489	1892
Bigger, F. J.	Notice of an Ancient Celtic Shrine	Belfast Nat. F. C.	*Report and Proc.*	III.	394	,,
Browne, Rev. Prof.	Early Sculptured Stone at West Camel, Somerset	Som'setsh. A. N. H. Soc.	*Proc.*	XXXVI.	70	1891
Chinnock, Dr. E. J.	The Connection between Saxon-English and Latin	Dum. Gal. N. H. A. Soc.	*Trans.*	7	115	,,
Coles, F. R.	The Prehistoric Colony at Anworth	,, ,,	,,	,,	17	,,

Corrie, J.	The Folklore of Glencairn	,, ,,	,,	,,	37, 75	,,
Dudgeon, P.	Remnants of an Ancient Language	,, ,,	,,	,,	54	,,
French, J.	On some Ancient Lake Remains at Felstead, with Notices of similar Remains in the Neighbourhood	Essex F. C.	*Essex Naturalist*	VI.	17	1892
Holmes, T. V.	Notes on a Box used in Smuggling on the Border Fifty Years ago	Cumb. West. Assoc.	*Trans.*	XVI.	35	,,
Jones, Rev. E.	Exploration of the Elbolton Cave	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	105	,,
Kemp, T.	A Peep at our Forefathers through Churchwardens' Accounts	Warw. N. A. F. C.	,,	36	37	,,
Knowles, T.	Some Ancient Burton Manuscripts	Burt. N. H. Arch. Soc.	*Trans.*	II.	90	,,
Knowles, W. J.	On the Occurrence of Flint Flakes in the Glacial Gravels of Ballyrudder, Co. Antrim	Belfast Nat. F. C.	*Report and Proc.*	III.	410	,,
Lett, Rev. H. W.	On the Cross of Donaghmoor, Co. Down	,, ,,	,, ,,	,,	390	,,
Mason, P. B.	The Irish Aran	Burt. N. H. Arch. Soc.	*Trans.*	II.	32	,,
Meyrick, E.	Anthropometrical Statistics	Marlb. Coll. N. H. Soc.	*Report*	XL.	176	,,
Moule, H. J.	Notes on the Stone Implements, &c., in the Dorset County Museum	Dorset N. H. A. F. C.	*Proc.*	XII.	16	1891
Müller, Prof. F. Max	On Language	Glasgow Phil. Soc.	,,	XXII.	157	,,
Page, J. Ll. W.	Inscribed Stone on Wensford Hill	Som'setsh. A. N. H. Soc.	,,	XXXVI.	82	,,
Prowse, Dr. A. B.	Language and Race	Bristol Nat. Soc.	,,	VI.	390	,,
Roeder, C. R.	Folklore Notes	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	289	,,
					323	1892
Seward, E.	Formation of a Record of Prehistoric Remains in Glamorganshire	Cardiff Nat. Soc.	*Trans.*	XXIII.	21	,,
Smart, Dr. W.	Our Ancient British Urns	Dorset N. H. A. F. C.	*Proc.*	XII.	180	1891
Stewart, H. F.	Early Sculptured Stones at Ramsbury	Marlb. Coll. N. H. Soc.	*Report*	XL.	94	1892
Swinnerton, F.	Pre-Aryan Remains at Glen Wyllin, Isle of Man	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	262	1891
Sworder, C. B.	Ancient Remains at Epping	Essex F. C.	*Essex Naturalist*	VI.	79	1892
Thomson, Rev. J. H.	Martyr Graves of Dumfriesshire	Dum. Gal. N. H. A. Soc.	*Trans.*	7	8	1891
Walkey, R. H.	The Relation of the Biblical Deluge to Archæology	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	259	,,
,, ,,	The Practice of Cremation in Neolithic Times	,, ,,	,, ,,	,,	311	1892
Wallace, Dr. W.	An Inquiry into the Nature of Heredity	Glasgow Phil. Soc.	*Proc.*	XXII.	227	1891

Report of the Committee, consisting of Lord McLaren (*Chairman*), Professor Crum Brown (*Secretary*), Dr. John Murray, Dr. A. Buchan, *the* Hon. Ralph Abercrombie, *and* Professor Copeland, *appointed for the purpose of co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.* (*Drawn up by* Dr. A. Buchan.)

During the past year the hourly eye observations by night and by day have been made at the Ben Nevis Observatory without interruption by Mr. Omond and the assistants. At the Low Level Observatory at Fort William, the continuous registration and other observations have been also successfully carried on as detailed in last year's report.

The Directors have been again indebted to Mr. R. C. Mossman, F.R.S.E., Mr. Drysdale, M.A., Mr. Craig, Mr. H. F. Rankin, and Mr. Stewart, B.Sc., from Professor Tait's Laboratory, who have generously given their services as observers for periods varying from four to eight weeks during the winter and summer months, thus extending much-needed relief to the regular members of the observing staff.

For the year 1891 the following were the monthly mean and extreme pressures, temperatures, hours of sunshine, amounts of rainfall, number of fair days, or days of less than 0·01 inch of rain, at the Observatory, the mean pressures at the top of the Ben being reduced to 32° F. only, while those at Fort William are reduced to 32° and sea-level (*see* table next page):—

The mean temperature of the whole year at Fort William was 47°·0, being 0°·2 under the mean of previous years. This was the deficiency in the temperature of 1891 over a large district surrounding Fort William. On the other hand, the mean temperature at the top of the mountain was 31°·3, or 0°·3 above the average of the year. The mean temperature at the top as compared with the bottom of the mountain was thus half a degree relatively warmer, and it may be noted that this excess of the annual temperature held good in insular situations to the west and south-west from Barrahead to Islay.

The lowest mean monthly temperature occurred at both Observatories in March, the mean at the top being 20°·0 which was also the mean for January 1886, this being the lowest monthly mean since the Observatory was opened. The highest monthly mean at the top was 43°·1 in June, and at Fort William 57°·7, also in June. The general character of the weather for the year was anti-cyclonic, with therefore a large amount of sunshine, and for the time of the year a small difference in the temperatures at the two Observatories. The temperature of February was very high, and the weather exceptionally fine. At Fort William temperature was 4°·1 above the average, but at the top the average was exceeded by 7°·5. This was by far the mildest winter month hitherto experienced by the observers. The weather was largely anti-cyclonic, and on many occasions the atmosphere was unusually dry, and temperatures were higher at the top than at Fort William at the same time. Consequently the difference between the mean temperatures at the top and bottom was unprecedentedly small, being indeed only approached in this respect by the singularly fine month of June 1887.

The maximum temperature for the year was 64°·9 at the top, and 79°·9 at Fort William, both in June; and in February temperatures of

1891	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Pressure in Inches.													
Ben Nevis Observatory	25·325	25·656	25·119	25·373	25·230	25·554	25·381	25·188	25·294	25·049	25·158	25·057	25·294
Fort William	29·989	30·303	29·782	29·999	29·794	30·054	29·880	29·659	29·792	29·601	29·751	29·675	29·857
Differences .	4·664	4·647	4·663	4·626	4·564	4·500	4·499	4·471	4·498	4·552	4·593	4·588	4·563
Mean Temperatures.													
Ben Nevis Observatory	23°·2	30°·6	20°·0	24°·1	29°·9	43°·1	40°·7	39°·0	38°·8	31°·5	28°·0	26°·4	31°·3
Fort William	38·4	43·1	37·9	42·6	47·7	57·7	57·0	56·0	54·2	47·5	41·2	40·8	47·0
Differences	15·2	12·5	17·9	18·5	17·8	14·6	18·3	17·0	15·4	16·0	13·2	14·4	15·7
Extremes of Temperature, Maxima.													
Ben Nevis Observatory	38°·1	43°·7	40°·0	35°·9	46°·1	64°·9	52°·8	49°·1	59°·0	44°·3	50°·6	35°·8	64°·9
Fort William	51·0	56·2	54·8	55·1	71·4	79·9	73·5	72·0	74·8	60·0	56·9	55·8	79·9
Differences .	12·9	12·5	14·8	19·2	25·3	15·0	20·7	22·9	15·8	15·7	6·3	20·0	15·0
Extremes of Temperature, Minima.													
Ben Nevis Observatory	11°·5	18°·1	5°·6	15°·8	14°·3	27°·2	29°·1	28°·8	27°·9	22°·4	18°·7	16°·1	5°·6
Fort William	22·7	28·9	17·2	28·0	31·0	36·0	44·0	36·4	35·4	26·8	23·8	26·8	17·2
Differences .	11·2	10·7	11·6	12·2	16·7	8·8	14·9	7·6	7·5	4·4	5·1	10·7	11·6
Rainfall in Inches.													
Ben Nevis Observatory	14·20	15·09	14·78	2·50	7·00	7·51	10·53	19·16	43·55	14·34	11·88	17·48	178·02
Fort William	7·88	7·42	4·37	1·41	2·20	3·27	3·68	8·37	13·02	9·38	6·01	11·80	78·81
Differences	6·32	7·67	10·41	1·09	4·80	4·24	6·85	10·79	30·53	4·96	5·87	5·68	99·21
Number of Days of no Rain.													
Ben Nevis Observatory	5	10	12	19	11	18	5	1	3	7	8	7	106
Fort William	8	9	13	21	18	19	14	5	5	8	10	8	138
Number of Days 1 *in. or more fell.*													
Ben Nevis Observatory	6	4	5	0	1	5	2	9	16	6	5	9	68
Fort William	3	3	1	0	0	0	0	2	3	1	1	4	18
Hours of Sunshine.													
Ben Nevis Observatory	14	87	92	109	104	212	84	44	46	61	31	24	908
Fort William	24	56	122	159	182	238	116	92	78	98	25	10	1,220
Differences .	10	—31	30	50	78	26	32	48	32	37	—6	—14	312

43°·7 and 56°·2 were recorded at these places respectively. The minimum temperature at the top was 5°·6, and at the bottom 17°·2, both in March. This gives for the top the unusually large range of 59°·3 of temperature for the year at the top of the Ben, being nearly 10°·0 larger than for the previous year. It may be here added that the minimum temperature recorded since the Observatory was opened was 3°·5 on March 27 at 6 A.M. of the present year.

The registrations of the sunshine-recorder show 908 hours out of a possible 4,470 hours. In 1890 the number was only 591 hours. In 1891 the maximum was 212 in June, and the minimum 14 in January. In February the unusually large number of 87 hours was recorded for this winter month, this being 31 hours greater than the sunshine at Fort William. At Fort William the number of hours for the year was 1,220,

being 312 hours in excess of the number of hours registered at the top. It may be pointed out that the number of hours of possible sunshine is, particularly in winter, considerably greater at the top than at Fort William, which is enclosed by hills.

The rainfall for the year was 178·02 inches; in 1890 the amount was 198·34 inches. These are by considerable amounts the heaviest annual rainfalls yet observed. At Fort William the amount was 78·81 inches, or nearly 100·00 inches less than on the top of the mountain. Hence while the rainfall at Fort William was the average, that of Ben Nevis was 24 per cent. above the average. The rainfall of September was phenomenal, amounting at the Observatory to 43·55 inches; the amount for the same month at Fort William being 13·02 inches. One inch of rain or upwards fell on each of 16 days of the month, and on the 1st 4·93 inches were recorded, and 3·37 inches on the 2nd. It is remarkable that during the extraordinarily heavy rains near the east coast on the 20th and 21st, the rainfall at the top of Ben Nevis was light; and on the other hand, while practically no rain fell in the east on the 17th, 18th, and 19th, the rainfall on the Ben amounted to 4·05 inches. At several of the stations of the Scottish Meteorological Society the rainfall over this part of Scotland was fully double the average of the month; but at the Observatory it was three times the average.

The number of days on which the rainfall was *nil*, or less than the hundredth of an inch, was 106, there being only one fair day in August, but the unusually large number of 19 fair days is reported in April, and 18 in June. At Fort William there were 138 fair days during 1891, and in April, May, and June 21, 18, and 19 are respectively recorded. Again, while at Fort William at least an inch of rain fell on 18 days during the year, there were 68 such days at the top of the Ben; and while at Fort William there was an entire absence of such wet days in April, May, June, and July, only in April at the top was no such wet day recorded.

At Fort William the mean atmospheric pressure was 29·857 inches, or 0·030 inch above the mean pressure. The monthly extremes were, the maximum 30·303 inches in February, and the minimum 29·601 inches in October, these being 0·328 inch above and 0·219 below the means respectively.

On the suggestion of Mr. J. Y. Buchanan, who has recently been examining some phases of the hygrometry of Ben Nevis in connection with the cloud and fog observations, it has been agreed to institute a systematic series of observations, having for their object a careful record of the height above sea-level of the lower surface of clouds that from time to time cover the side of the mountain facing Fort William. The importance of this new series of observations will be recognised when the large portion of the year the Observatory is enveloped with a completely saturated atmosphere is taken into consideration.

Mr. R. C. Mossman has investigated the remarkable squall which occurred in the British Islands on the morning of February 1, 1892. The more important of the results are the rapid rate, about forty miles an hour, with which it swept over the country from N.W. to S.E., the sudden fall and equally rapid rise of pressure being at many places fully six-hundredths of an inch, the sudden great fall of temperature fully ten degrees at many places, and the sudden change of wind. These features are well marked in the Ben Nevis observations, which show well, among

other points, the great height in the atmosphere the squall reached, bearing in its train totally changed conditions of temperature and moisture. Mr. Mossman has been engaged in discussing the remarkable series of observations made by Mr. Wragge in 1882 at eight stations well distributed up the slopes of Ben Nevis from Fort William to the top. The work is so far advanced as to indicate the important bearing of the results as regards the vertical distribution of pressure, temperature, and moisture during the changes of weather of that year.

Steps have been taken to make the observation of dust particles in the atmosphere part of the regular work of the Observatory. Eight observations are made daily, and as each of these eight is the mean of ten, there are really eighty of these observations made every day. The observations now accumulated amply confirm the tentative results given in your Committee's last year's report, as showing a well-marked diurnal variation. Further, dry, thick fog is shown to contain a great amount of dust, but thin, wet mist very little. It is when a thin drizzling mist envelops the summit that the lowest values are obtained, and the all-important observation has been made, after consulting the daily weather maps of Europe at the time, that the winds differ in direction 90°, or even more, from the winds then prevailing near sea-level. In other words, the drizzling and practically dustless winds blow out from a shallow cyclone overspreading this part of Europe at the time. The significance to weather forecasting of these different types of wind, as regards dustiness, or dustlessness, to the cyclones and anti-cyclones prevailing is too evident to call for further remark.

In your Committee's last report, expression was given to a desire that a system of special observations on the hygrometry of the atmosphere be instituted at the two Observatories, with the view of arriving at some accurate knowledge of the absolute amounts of aqueous vapour at different heights under the different weather conditions. With reference to this, the Directors of Ben Nevis Observatory report that the University of Edinburgh has awarded the Scholarship placed at their disposal by the Commissioners of the Exhibition of 1851 to Mr. A. J. Herbertson; and that the research to which he will devote his attention during the two years he holds the scholarship is the hygrometry of the atmosphere, and it is understood that the investigation will begin at Ben Nevis Observatory, and will proceed on the lines indicated by the Directors.

During the past year Mr. Omond has been engaged in an important inquiry into the relations of the Ben Nevis High and Low Level Observatories to the cyclones and anti-cyclones, or the weather changes of the British Islands. In this large inquiry the instances dealt with are arranged into eight groups, according to the direction, N., N.E., E., &c., of the gradient from Ben Nevis in the direction of the cyclone or anti-cyclone. To these are added two groups, first when Ben Nevis is inside the highest isobar; and second, when it is inside the lowest isobar; in other words, when the Observatories are approximately either in the centre of an anti-cyclone or of a cyclone.

Dr. Buchan is investigating the observations at the two Observatories during February and September, 1891, in their relations to the changes of weather. These two months have been selected owing to the exceptional character of the weather which prevailed, and the admirable illustrations afforded of the more striking meteorological conditions, and meteorological contrasts of the two Observatories, and other striking

meteorological phenomena already referred to in our previous reports. A considerable proportion of the observations beginning with July 1890, when the Low Level Observatory was fully equipped, having been rearranged on daily sheets, on which hour by hour the double set of observations are contrasted, and the changes noted from each hour to the hour following. These changes are then compared with the bi-daily weather maps of the Meteorological Council, and more particularly with the observations made at the stations of the Scottish Meteorological Society, which include the valuable observations made at the northern lighthouses of storms of wind and rain, and other phenomena, which are made night and day by the keepers of the lighthouses.

Seventh Report of the Committee, consisting of Professor FITZGERALD (*Chairman*), Professors H. E. ARMSTRONG *and* O. J. LODGE (*Secretaries*), Professors Lord KELVIN, Lord RAYLEIGH, J. J. THOMSON, A. SCHUSTER, J. H. POYNTING, A. CRUM BROWN, W. RAMSAY, E. FRANKLAND, W. A. TILDEN, W. N. HARTLEY, S. P. THOMPSON, W. C. ROBERTS-AUSTEN, A. W. RÜCKER, A. W. REINOLD, G. CAREY FOSTER, *and* H. B. DIXON, Captain W. DE W. ABNEY, Drs. J. H. GLADSTONE, J. HOPKINSON, *and* A. J. FLEMING, *and* Messrs. W. CROOKES, SHELFORD BIDWELL, W. N. SHAW, J. LARMOR, J. T. BOTTOMLEY, R. T. GLAZEBROOK, J. BROWN, E. J. LOVE, *and* JOHN M. THOMSON, *appointed to consider the subject of Electrolysis in its Physical and Chemical Bearings.*

THE document referred to in last year's report as being drawn up by the Rev. T. C. Fitzpatrick, of Christ's College and Cavendish Laboratory, Cambridge, is now nearly finished, and represents a great amount of labour, for which the best thanks of the Committee are due to the compiler. It consists of a table summarising the results obtained by many experimenters on the electro-chemical properties of solutions in water, and gives, for various concentrations, the conductivity, migration, and viscosity data of a great variety of salts. It will be printed in next year's report.

The work of the active members of the Committee is proceeding, but it is not in a condition for annual reports. In the opinion of the members present at a meeting held in Edinburgh it was thought best to suspend the official existence of the Committee for a time in order to be able to make a more full and satisfactory report on the progress achieved after the lapse of a few years. They therefore do not at present ask for reappointment.

Report of the Committee, consisting of Professor O. J. LODGE, Mr. A. P. CHATTOCK, *and* Professor G. CAREY FOSTER, *appointed to investigate the phenomena accompanying the Discharge of Electricity from Points.* (*Drawn up by* Mr. A. P. CHATTOCK.)

DURING the past year a large number of experiments have been made on the passage of sparks between points and flat plates, especially with regard to the differences exhibited by the two kinds of electricity in this

respect. It was hoped that the results thus obtained would have been sufficiently complete to submit to the meeting this year, but owing to unavoidable delays in carrying out the experiments this is not the case. The main conclusion, however, appears, so far, to be that in the formation of sparks the anode is a far more important factor than the cathode, disturbing influences having little or no effect when applied to the latter, though they may prevent the passage of sparks altogether if applied to the anode. This is in accordance with Lehmann's recently described experiment on the effect of a strong blast of air upon sparks. It is also borne out by experiments now in progress on the critical distance between a point and a plate at which discharge from the point changes from the form of a silent glow to that of a spark, the distance being appreciably greater when the point is the anode than when it is the cathode.

Another line of investigation, which was indicated in last year's report, has been followed up in the attempt to measure the ratio of the mass of the gas molecules concerned in carrying a current of electricity to the quantity of electricity carried. The discharge being arranged to take place convectively along a non-conducting tube of uniform bore, the slopes of mechanical pressure and electrical potential along its axis are determined. The apparatus for this purpose has undergone many changes, chiefly on account of the difficulty experienced in bringing the electrometer to the potential of that part of the tube with which it is connected. Stationary conductors within the tube were found to be unreliable for this purpose, and a modification of the well-known ' water-dropper ' has therefore been adopted in the latest form of the instrument. The slope of potential is measured by observing the differences of potential between successive pairs of positions one centimetre distant from each other along the tube. The electrometer has thus to measure small differences of potential at a high mean potential with respect to the earth. For this purpose an instrument has been specially designed, from which the leakage to earth seems negligible. To obtain the slope of pressure in the discharge tube the motion of an indiarubber diaphragm, separating two air-tight chambers, is observed, the chambers being connected, like the terminals of the electrometer, to successive pairs of points along the tube, and the movement of the diaphragm being magnified optically. A difference of pressure of about five dynes per square centimetre causes a movement of one scale division in the present instrument, and this is found to be quite sufficient for the purpose. With this apparatus it is hoped that reliable results will shortly be obtained.

Finally, preparations are being made to extend the measurements already obtained of the strength of field at a discharging point to higher than atmospheric pressures. For this purpose a powerful compression pump and a strong discharge chamber are being constructed. Upon the assumption that discharge occurs by the breaking down of electrically polarised molecular chains in the gas, it is possible to obtain from such measurements another rough estimate of the value of the electrical charge associated with a gas atom, by extrapolating to the pressure at which the gas molecules are brought close together. It seems desirable to obtain all the evidence possible which bears upon this important point.

Your Committee ask for reappointment without a grant.

Second Report of the Committee, consisting of Professor Liveing, Dr. C. Piazzi Smyth (*Secretary*), *and* Professors Dewar *and* Schuster, *appointed to co-operate with* Dr. C. Piazzi Smyth *in his researches on the Ultra-violet Rays of the Solar Spectrum.*

The present report is on the proposed experiments (from September, 1891, to January, 1892) for enabling Dr. C. Piazzi Smyth to improve certain points in the taking of his solar-spectrum photographs in the ultra-violet by aid of additions to the apparatus obtained through means of a grant from the British Association at Leeds in 1890.

The Report continuates the last one by the same committee, as printed in the British Association's Cardiff volume of 1891, at pp. 147 and 148 thereof, said space being then taken up with little more than descriptions of what the apparatus, then only just finished, was intended for. Now, however, a sufficient amount of experiments have been obtained to allow the results to be classified and collated under three several heads, or thus:—

(1) Improved focussing means for setting the focus of the viewing, or photographic telescope, both more accurately and easily as well, from previous book-record, rather than from renewed eye-and-hand observation on every occasion. This was carried out mainly and successfully by supplying wheels ten inches in diameter, and nicely graduated on their circumferences, to either end of the ordinary axle of pinion-movement of the focussing tube, taking care also to turn the said pinion at the last moment in the direction of increasing the readings and noting what they were. This record method of focussing, too, it is believed, is one which will be found of very general application, and much used every coming year, now that photography is continually substituting more and more the observer's eye and hand, with almost all kinds of optical notation of luminous phenomena.

(2) Improved magnifying means were next required for the viewing, and equally photographing, telescope. The chief feature necessary here was a large field with the increased magnifying power, and was given to a considerable extent by a grand Barlow-achromatic concave lens placed inside the usual telescope tube, by Messrs. T. Cooke & Sons, of York.

For mere magnifying, however, wherever the part of the spectrum under examination permits it without other addition, I have since then fully made up my mind that the second order of Professor Rowland's later and unprecedentedly fine Gratings from his new ruling engine, give sharper magnifying to the spectrum than any lens I have experimented with.

But they give it in a different way, *i.e.* the second orders of Grating's spectra do; for they magnify only in one direction—that of separation—while a lens magnifies in a direction at right angles to that also. That feature is no doubt so much the worse for the lens, because it weakens the intensity of a continuous spectrum operated upon by it. But then there is another feature which is bad for the second, or any subsequently still more magnified, spectrum-order of a Grating, viz. that they admit the red light of a previous order in the middle of their own violet; unless some possibly very absorptive liquid be employed to stop such red light where it is not wanted.

Conspectus of practical data, touching a continuous series of photos, extending into the ultra-violet of the Solar Spectrum, when extra-magnified from a Grating's first order of spectra only, by Messrs. T. Cooke & Sons' Barlow's achromatic concave lens.

R.S.E. Plates' Nos.	Spectrum lettered lines	Finders's place for plates' centres	Oscillation frequency, in 1″ British	Visual focus	Photographic focus	Exposure in minutes	Number of proofs obtained	Their dates when photographed, 1891	Box numbers holding them	Remarks
49	*d*	11·905	56,750	18·8	22·6	1·5	3	September 7, 9, 9		These photographs are the original negatives taken on small glass plates at the eye-end of the viewing telescope of the Clova Spectroscope. Whether they are sufficiently well defined to bear large magnifying remains to be seen, but they are quite free from red light. Meanwhile attention is directed to the rapidly increasing focal length towards the end of the table, and the still more rapidly increasing exposures required there also. The series of photographs of the previous years 1889 and 1890, exhibited at the British Association Cardiff Meeting in 1891, was obtained from the *second* order of the same Grating's spectra, with anti-red media between, but ended with plate 74.
50		11·930	57,250	20·8	24·0	1·0	2	September 7, 12		
51		11·950	57,750	23·1	26·0	1·0	2	September, 11, 12	3	
52	*e*	11·973	58,250	25·6	28·0	0·8	2	September 11, 12		
53	*f*	12·000	58,750	28·5	30·8	1·0	2	September 12, 12		
54	G	12·013	59,250	31·5	33·7	1·0	2	August 21, 21		
55		12·034	59,750	35·0	37·1	0·8	2	September 15, 26		
56	*g*	12·050	60,250	All spectrum *visibility* ends here with my spectroscope and eye	40·4	0·8	2	September 15, 23		
57		12·072	60,750		43·6	1·0	2	September 23, 25	4	
58		12·091	61,250		47·2	1·0	2	September 15, 25		
59		12·109	61,750		51·0	1·0	2	September, 23, 25		
60		12·128	62,250	—	55·1	0·9	2	September 15, 26		
61		12·147	62,750	—	59·3	1·0	2	September 23, 26		
62		12·163	63,250	—	63·8	0·9	2	September 26, 28		
63		12·182	63,750	—	69·6	1·0	3	September 28; December 14, 14		
64 [1]		12·198	64,250	—	75·0	2·0	3	September 30; October 17, 24	5	
65	H	12·215	64,750	—	80·5	1·5	3	September 30; October 21, 24		
66	K	12·232	65,250	—	86·5	2·0	3	September 30; October 21, 27		
67		12·248	65,750	—	92·2	2·0	3	September 30; October 21, 28		
68		12·265	66,250	—	98·0	3·0	3	November 17; December 11, 14	6	
69	L	12·283	66,750	—	103·8	4·0	2	November 17, 27		
70		12·295	67,250	—	110·0	5·0	2	November 19, 27		
71		12·312	67,750	—	116·6	5·5	2	November 17, 19		
72	M	12·329	68,250	—	123·6	6·0	2	November 19, 27		
73		12·350	68,750	—	131·0	6·5	2	November 19, 27	7	
74		12·370	69,250	—	139·0	9·0	2	November 19, 27		
75		12·387	69,750	—	148·0	10·0	3	November 19; December 14, 14		
76		12·400	70,250	—	157·0	11·0	2	November 19, 27		
77	N	12·415	70,750	—	166·0	12·0	2	November 27; December 14		
78		12·430	71,250	—	176·0	13·0	2	November 27; December 14	8	

[1] Add two more photos of same subject, '64,' taken on January 25, 1892, and on January 30, 1892 . . . . . .

making the whole number of photographs constituting this series = 70, but the number of natural subjects only 30.

Now Messrs. Cooke's Barlow concave lens wants no help of that kind, for it was constructed to magnify the first order of spectrum only, and that has no red light of any other order intruding into its own ultra-violet, or requiring some chemical liquid to dull its potency. Hence I have actually found that I have been able to carry Messrs. Cooke's lenticular magnifying of the first order of a Grating's spectrum, four plates further into the invisible, than I was able to do with the second order of the very same Grating's spectra, assisted in various chromatic modes. As an illustration of which I beg to append a list of spectrum photographs so obtained last autumn.

(3) Lastly, my attention was kindly and earnestly directed by Professor Liveing to keep on the look-out for possible changes in some part or parts of the solar spectrum, depending on time and date only, especially if their origin should appear to be in the Sun.

Now it did so happen one morning that one of the glass negatives of the H and K region of the solar spectrum did show a very strange and anomalous difference from all the others, so different indeed that my first impression was to throw it away as irretrievably spoilt by some accident. But on considering what such an accident could be, or how it could be reproduced if desired, I was still more confounded and nonplussed. Having, moreover, Professor Liveing's letter still before me, the most respectful course seemed to be, on second thoughts, to describe publicly how the anomaly brought itself forward so far as I knew, and to leave gentlemen with more experience than myself to form their own opinions, either for or against its being anything important.

Now the main point of the anomaly is, that the whole space between H and K is bright, while that outside them is dark, even very dark. To understand which feature thoroughly and in the terms worked in by Nature, it was necessary that there should be several plates employed, and each of them should show, not only the whole space between those giant lines or bands, but at least as much more on either side.

Moreover, as good definition does not continue to hold all along even so small a plate of glass as a quarter size, but has to be set and reset several times in its course, while the appearance of the lines alters almost radically on account of the mere curvature of the field, I enclose in an album case in the first place thirteen ordinary photographs of the H and K lines, taken at successive foci all across the field, and then three various impressions from one and the same anomalous photograph, No. 14; following that by Nos. 15 and 16, ordinary, but focussed to the right, views: the whole eighteen now exhibited being enlarged on paper to six times the size of the glasses, for convenience of examination. And I should perhaps duly forewarn all and sundry that 'date' plays no part in the arrangement of this bundle of repetitions of the H and K lines—only the continual progress from left to right of the place of sharpest definition.

Second Report of the Committee, consisting of Mr. G. J. Symons (*Chairman*), Professor R. Meldola, Mr. J. Hopkinson, *and* Mr. A. W. Clayden (*Secretary*), *appointed to consider the application of Photography to the Elucidation of Meteorological Phenomena.* (*Drawn up by the Secretary.*)

Your Committee report that the work has been continued during the past year on the lines laid down in the Report for 1891.

Considerable additions have been made to the number of observers from whom assistance may be expected, in spite of the removal of several names from last year's list.

The total number of photographs received up to July 23 was 361, representing a variety of phenomena, but chiefly illustrating the results obtainable in cloud photography by various methods. This number, however, does not adequately represent the progress made, for many other photographs have been promised, and will in all probability be received in a few weeks.

The adoption by the majority of the International Meteorological Congress at Munich of the classification of clouds, proposed by Messrs. Hildebrandson and Abercromby, suggested to your Committee that it would be well for them to adopt it, at least provisionally. They cordially agree with the action of the English delegates at the Congress in opposing the acceptance of a system which is entirely empirical; but since the great majority of foreign meteorologists have determined to employ it, your Committee consider that they should adopt it provisionally. They think it will be well to follow the example set by other countries until the further study of cloud-forms, and their relation to one another, render it possible to make a more scientific code.

Arrangements have therefore been made for the cataloguing of the collections of meteorological photographs in the possession of the Royal Meteorological Society, and of the Chairman of your Committee.

Photographs of Lightning.

Very few new photographs have been sent in as yet, but from Mr. J. H. Bateman two of great interest have been received. Following the suggestions in the instructions issued last year, two cameras were employed, the first being stationary, and the second moved rapidly from side to side. The plate exposed in the fixed camera shows four flashes, while the one which was moved shows six. A flash which is single on the fixed plate is resolved into three on the moving plate, showing that the flash did consist of a series of discharges along much the same path. The absence of reduplication in the others points to the conclusion that they were single. Two of these single flashes occupy exactly the same relative positions on the two plates, showing that they must have been simultaneous.

Your Committee regret that there should have been no opportunity of carrying out any further experiments upon the phenomena presented by lightning photographs. However, recent discoveries concerning high-tension discharges ought to elucidate the subject. Thus it seems highly probable that the hazy continuous luminosity shown by many photographs may be due to the flame of burning nitrogen.

Before leaving the subject of lightning, it may be pointed out that in

Mr. Bateman's photographs the narrow ribbon structure in each flash is not more pronounced in the moving photograph than in the one which was stationary.

The Royal Meteorological Society has received several new photographs of lightning. They all show the narrow ribbon structure; one shows reduplication of the images of some chimneys as well as the flash, while another shows a bright flash and several dark ones. Of this last Mr. Robert Law, who took the negative at Melbourne, remarks that there were two flashes, the second reversing the image of the first.

Methods of Cloud Photography.

The information at the disposal of your Committee does not, as yet, seem sufficient to enable them to pronounce definitely in favour of any one method as the best. They have made some progress in ascertaining the methods adopted abroad, and also in experimental work at home. The subject divides itself naturally into two sections, dealing respectively with cumulus or heavy clouds, and with cirrus or other light clouds.

Cumulus.—With all heavy clouds it is certain that admirable results may be obtained with a little practice in adjusting the stop and length of exposure. So far as the quality of the results obtainable is concerned, there does not seem to be any manifest advantage in the use of a coloured screen, of a black mirror, of specially slow, or of orthochromatic plates. Nevertheless, it is quite certain that results of a given excellence are more easily obtained on a slow plate with a strong developer considerably restrained. It is equally certain that the use of the coloured screen, or of the black mirror, renders the process easier still.

With correct exposure and careful development it should not be necessary to resort to intensification of the image. If some such treatment should be required, inexperienced observers should be warned that in the use of mercurial salts it is well to keep the plate in constant movement while in the mercury bath, in order to avoid undue granulation of the image.

Cirrus.—Those who have made a special study of the photography of thin clouds appear to be agreed that in order to bring out all the details of their structure some special device must be adopted.

By extremely nice adjustment of the exposure and subsequent intensification of the image, very fair results can be sometimes obtained; but the process is difficult, and only practicable in experienced hands.

Dr. Riggenbach, who first described the black mirror device, recommends that exposure should be so arranged that the sky leaves practically no impression on the plate, while the thin image of the cloud must be intensified by means of Schlippe's salt (sulphantimoniate of soda).

M. Angot, in a report presented to the Meteorological Society of France, remarks that a black mirror is only advantageous when the cloud is about 90° from the sun. In theory this is of course correct, but the Secretary to your Committee has found that there is a manifest practical advantage in its use for all parts of the sky, including even the immediate neighbourhood of the sun itself. M. Angot then goes on to say: 'The best results are obtained by coloured screens, yet the ordinary screens are insufficient. The following formula, due to M. Léon Vidal, gives every satisfaction. In a small glass trough with parallel faces there is placed a solution made with the proportions—sulphate of copper 175 grams, bichromate of potash 17 grams, sulphuric acid 2 cubic centimetres. These are dissolved in 100 to 500 cubic centimetres of

water, according to the thickness of the trough and the results to be obtained. The sulphate of copper arrests the red rays, and the bichromate the blue and violet. The plates used were Lunière's orthochromatic, and the exposure from ·5 to ·8 second.'

Your Committee regret that they have not yet received any illustrations of the results obtainable by the above means, but it is hoped that an exhaustive trial of the method may be carried out in the course of the coming year.

The Secretary to your Committee has continued the comparative trial of slow and ordinary plates with or without a black mirror. He reports that ordinary plates and direct exposure may often give satisfactory results when the background of sky is a clear deep blue. If, however, it is at all hazy, the correct exposure becomes extremely difficult. With slow plates, however, such as Mawson & Swan's transparency plates or photomechanical plates, it is fairly easy to obtain results of considerable excellence.

With the black mirror ordinary plates give excellent results; but here again, unless the clouds are moving with unusual rapidity, or unless the light is very bad, there is a great advantage in the use of slow plates. It is, indeed, easy to obtain a fairly dense image of any cloud, however luminous and however thin, by the combined use of mirror and slow plate. Such means give abundant detail and full gradation of light and shade, even when the sun is actually in the field of view. Exposure would vary from about ·2 to about ·8 second with an aperture $\frac{f}{11}$.

The developer used in all these experiments is the familiar formula with pyrogallol and sulphite of soda considerably restrained.

Special attention should be drawn to the admirable series of cloud studies presented to the Committee which were taken by Signor Mannucci at the Vatican Observatory under the direction of the Rev. Padre Denza, S.J. These show what can be done by direct exposure, Signor Mannucci recommending a slow plate for the more difficult subjects. The pictures taken by the Secretary to your Committee in a similar manner show the value of the slow plate and black mirror.

Miscellaneous Photographs.

With regard to miscellaneous photographs of meteorological interest, your Committee regard with some satisfaction the number of pictures they have been able to secure which show the violence and severity with which the great blizzard of March 1891 visited the South-west of England. They believe it is of great importance that fairly complete pictorial records should be kept of all such abnormal events.

They are also pleased to be able to report that several of the photographic periodicals have recently manifested considerable interest in the work, one paper, the 'Practical Photographer,' having just offered a series of prizes for the best meteorological studies; and the editor has promised to present any competing pictures to your Committee. Several photographic societies are also taking the matter up, and your Committee hope that the effect of such powerful aid may rapidly make itself felt, both by increasing their collection and by adding to the number of contributors.

In order to show the widespread interest already taken in the subject, brief catalogues of the three principal collections are appended.

In conclusion, your Committee ask to be re-appointed with a grant of 15*l.*, in order to follow up properly what they regard as a satisfactory start.

Additions to the Committee's Collection.

Regd. No.	Size	By whom taken	When	Where	Remarks
		CLASS A.—*Clouds.*			
	Inches				
101–132	$6 \times 4\frac{1}{4}$	Frederic Mannucci .	—	The Vatican Observatory, Rome	A series of studies taken under the direction of the Rev. Padre Denza, S.J. All taken by direct exposure, some on ordinary plates, some on slow plates, some on isochromatic plates.
133–141	6×4	A. E. Western . .	—	Near Marlborough .	Cumulus; comparison between ordinary and orthochromatic plates.
142–143	$4 \times 2\frac{3}{4}$	J. H. Bateman . .	—	Worthing . . .	Showing beginning of small waterspout funnel.
144–145	$4 \times 2\frac{3}{4}$	J. Hopkinson . . .	—	—	Two sunsets, showing cloud changes.
146–148	$7\frac{3}{4} \times 6$	C. Meldrum . . .	—	Mauritius . . .	—
149–152	$6 \times 4\frac{1}{4}$	Eliot Curwen . . .	1891	At sea . . .	—
153	$21 \times 9\frac{1}{2}$	Dr. Tempest Anderson .	1890	Iceland . . .	Under the cloud cap which generally hangs over the desert in the south-west of Iceland.
154–254	Various, $4 \times 4\frac{3}{4}$ up to 15×12	A. W. Clayden . .	1891–1892	Plymouth and London	A series of studies of cloud forms, mostly cirrus and cirro-cumulus. The results of experiments with slow and with ordinary plates, with and without a black mirror.
		CLASS B.—*Lightning.*			
13	8×6	J. H. Bateman . .	—	Worthing . . .	No. 13, taken in a fixed camera.
14	$4 \times 2\frac{3}{4}$	" " . . .	—	" . . .	No. 14, camera moved. These two photographs represent

16	$4 \times 2\frac{1}{4}$	F. H. Glew . . .	June 28, 1892	Clapham Road . .	Triple flash taken with oscillating lens.
17–18	6×4	A. Roods . . .	„	Croydon . . .	—

CLASS C.—*Damage by Lightning.*

11–13	8×6	F. Holmes . .	July 23, 1891	Thornbury, Gloucester	Splintered oaks, illustrating a paper by Dr. Ernest Cook, Q.J.R.Met.Soc. April, 1892.

CLASS F.—*Snowfall, &c.*

5–16	6×8	Heath & Son . . .	March, 1891	Near Plymouth . .	Showing effects of the great blizzard of March 10, 1891.
17–20	Various	E. H. Micklewood . .	„	„ „ . .	„ „
21–25	$3 \times 2\frac{3}{4}$	Rev. J. Henning . .	„	Kingsbridge . .	„ „
26–29	6×4	Valentine & Sons . .	„	Teignmouth . .	„ „
30–31	$3 \times 2\frac{3}{4}$	E. Marriott . . .	„	Reedham . . .	„ „
32	3×2	E. Askew . . .	March, 1892	South Molton . .	—
33	$3 \times 2\frac{3}{4}$	A. W. Clayden . .	Good Friday, 1892	Plymouth . . .	—
34–36	$3 \times 2\frac{3}{4}$	Admiral J. P. Maclear .	Easter, 1892	Cranleigh . . .	—
37	8×6	G. Denney & Co. . .	March, 1891	Teignmouth . .	Effects of blizzard.
38	$7\frac{1}{2} \times 4\frac{1}{2}$	„ „ . .	March 10, 1891	„ . .	Showing steam blown ahead of express train.
39	5×4	Rev. H. D. Nicholson .	March, 1891	Walreddon Manor .	Blizzard
40	5×4	„ „ .	„	„ „ .	Interior of window.

CLASS H.—*Hoar-frost.*

9–10	Small	A. S. Herschel, F.R.S. .	—	—	Hoar-frost on wire lattice.
11	4×3	„ „ .	—	—	Hoar-frost on tree.

CLASS M.—*Ice Crystals.*

4	$6\frac{1}{2} \times 4\frac{1}{2}$	J. Martin . . .	—	New Southgate . .	Arborescent ice crystals.
5	6×6	„ „ . . .	—	„ „ .	„ „

Regd. No.	Size	By whom taken	When	Where	Remarks
		CLASS A.m.—*Clouds.*			
	Inches				
1	6 × 4	Dr. F. G. Drewitt . .	June 18, 1889	Northamptonshire .	Thunder clouds.
2–18	8 × 5 to 10 × 8	P. Garnier . . .	1889	Boulogne-sur-Seine .	Various clouds.
19	$6\frac{1}{2} \times 4$	F. Greene . . .	—	—	Cumulus.
20–23	$12 \times 8\frac{3}{4}$	T. Gordon . . .	1890	Whitehaven . .	Sunset skies.
24	$9\frac{1}{2} \times 7\frac{3}{4}$	C. Harrison . . .	September, 1889	Alvona Bay, Dalmatia	Cumulus on mountains.
25–28	$7\frac{1}{2} \times 4\frac{1}{2}$	Lovell . . .	December, 1882	Summit of Mt. Hamilton, California	Stratus. Mountain cloud.
29–33	4 × 3 to $8\frac{1}{2} \times 4\frac{1}{4}$	Admiral J. P. Maclear .	1888	Cranleigh . . .	Nimbus and stratus.
34–37	$6 \times 4\frac{1}{2}$ to $8\frac{1}{2} \times 6\frac{1}{4}$	H. Mellish . . .	—	Hodsock . . .	Thunder clouds.
38	$9 \times 6\frac{3}{4}$	C. Mousette . . .	July 16, 1887	Auteuil . . .	Cirrus and cumulus.
39–45	$6\frac{1}{4} \times 4\frac{1}{4}$	G. W. Ormerod . .	—	Teignmouth . .	Stratus and cumulus.
47–48	$6 \times 4\frac{1}{4}$	E. T. Shepherd . .	—	Parana, South Brazil	Cumulus.
49–53	8 × 6	Dr. F. G. Smart . .	August 3, 1891	Tunbridge Wells .	Thunder clouds.
54–59	$3\frac{3}{4} \times 2\frac{1}{2}$	W. C. Storey . . .	1890	Queensland . .	Cumulus and stratus.
60–64	4 × 3	Captain D. Wilson-Barker	—	Massowah, and at sea	Various clouds.
66–73	—	—	1887	Pic du Midi . .	Views from observatory.
74–174	$6\frac{1}{4} \times 4\frac{3}{4}$	Dr. A. Riggenbach . .	1890–1891	Säntis Observatory, Basle, and Zimmerwald	A fine collection of typical clouds.
175–176	$6\frac{1}{2} \times 4\frac{1}{4}$	—	June 6, 1887	Jamestown, Dakota .	Tornado cloud funnel.
177	$7\frac{1}{2} \times 4\frac{1}{4}$	E. E. Moulton . .	June 22, 1888	New Hampshire .	Spiral funnel at considerable altitude.
		CLASS B.m.—*Lightning.*			
1	$3\frac{3}{4} \times 3$	H. J. Adams . . .	September 2, 1889	Beckenham . .	Branched flash.
2–3	$6\frac{1}{4} \times 4$	G. R. Allerton . .	July 12, 1884	Mount Vernon, N.Y..	„ „
4	6 × 4	E. H. Allis . . .	July, 1888	Rosebank, Cape Town	„ „
5–12	$4\frac{1}{4} \times 3\frac{1}{4}$	W. Archibald . . .	September 25, 1891	Newark, N.J. . .	Various types.
13–14	$5\frac{3}{4} \times 4$	M. Auty	August 9, 1884	Tynemouth . .	—

15	$6\frac{1}{4} \times 4\frac{1}{2}$	G. E. Baker	August 17, 1887	Blomefield Terrace, S.W.	—
16–17	$6 \times 4\frac{1}{4}$	E. A. Barton	„	—	Single flashes.
18	$3\frac{1}{2} \times 2\frac{1}{2}$	Père G. Bastoul	July 26, 1891	St. Palais-sur-Mer	Numerous flashes.
19	4×3	J. H. Bateman	August 17, 1887	Streatham	—
20	$5\frac{1}{2} \times 3\frac{3}{4}$	R. C. Bayley	June 20, 1888	Peterborough	—
21	$5\frac{1}{4} \times 4$	A. W. Bates	August 17, 1887	Putney	—
22	12×7	„ „	June 6, 1889	„	—
23	$6\frac{1}{4} \times 4$	M. O. Berggren	October 2, 1891	Uddevalla	—
24	$8\frac{1}{4} \times 5$	A. H. Binden	June 23, 1888	Wakefield, Mass.	—
25–26	$5\frac{1}{2} \times 3\frac{1}{2}$	V. Blanchard and Lunn	June 6, 1889	Cambridge	—
27	Stereo	H. Butler	—	Vermilion, Dakota	—
28–30	8×6	L. S. Clarke	—	Pennsylvania	Various.
31–33	—	A. W. Clayden	—	—	See Committee's collection.
34–38	$4 \times 2\frac{3}{4}$	G. Carden	August 17, 1887	Croydon	Various.
39–40	$7\frac{3}{4} \times 4\frac{1}{2}$	G. E. Davis	July 17, 1887	Dubuque, Ia.	—
41	$8\frac{1}{4} \times 6\frac{1}{4}$	Hon. F. S. Dobson	December 12, 1887	Near Melbourne	—
42–43	6×4	Dr. F. G. Drewitt	October 6, 1886	Bournemouth	Reduplicated flash.
44	$6\frac{1}{4} \times 4\frac{1}{2}$	J. R. Ellis	June 6, 1889	Cambridge	Numerous flashes.
45	$5\frac{1}{2} \times 3\frac{3}{4}$	E. E. van Epps	—	Oberlin, Kas.	—
46	$5\frac{1}{2} \times 4$	R. H. Gill	June 6, 1889	Woodside Park, N.	—
47–49	6×4	A. Godman	„	St. Albans	—
50–52	6×4	E. C. Colledge	„	Ilford	Various.
53	$5\frac{1}{2} \times 3\frac{3}{4}$	J. Guardia	August 17, 1887	Clapham	—
54–59	Various	R. Haensal	June 6, 1885	Bohemia	Various.
60	3×2	F. Haes	June 6, 1889	Banet Road, W.	—
61	$7\frac{1}{2} \times 5\frac{1}{4}$	R. Harris	October, 1888	Amzinto, Natal	—
62	6×4	G. F. Harvey	1886	Putney	—
63–66	6×4	H. Haward	—	Calcutta	Various.
67–71	4×3	W. Hawksworth	January 30, 1888	Hawkwood, Natal	„
72	$6 \times 3\frac{3}{4}$	H. T. Hicks	May 19, 1890	Ramsgate	—
73	$4\frac{3}{4} \times 4$	W. W. Hirst	July 17, 1890	Pennsylvania	—
74–76	Various	Dr. H. Hoffert	—	Ealing	See Committee's collection.
77	$7\frac{3}{4} \times 4\frac{1}{4}$	M. I'Anson	June 15, 1888	Newark, N.J.	—
78–80	$5\frac{3}{4} \times 4$	A. C. Jeffery	—	Queensland	—
81–82	$4\frac{1}{2} \times 4\frac{3}{4}$	W. N. Jennings	—	Philadelphia	—
83–84	4×2	F. J. Kavanagh, S. J.	June 23, 1890	Montreal	—
85	$4\frac{1}{4} \times 1\frac{3}{4}$	R. Law	October 29, 1881	Melbourne	—

PHOTOGRAPHS IN THE POSSESSION OF THE ROYAL METEOROLOGICAL SOCIETY—*continued.*

Regd. No.	Size	By whom taken	When	Where	Remarks
	Inches				
86–87	$4\frac{1}{4} \times 3\frac{1}{4}$	R. H. Lawrence	—	New York	—
88	$8\frac{1}{4} \times 8\frac{1}{4}$	E. M'Clellan	June 6, 1889	Greenwich	—
89	$3\frac{3}{4} \times 2\frac{1}{2}$	L. Medland	„	Finchley	—
90	$9\frac{1}{2} \times 7\frac{3}{4}$	— Millard	—	Wigan	—
91	$5 \times 5\frac{3}{4}$	— M'Killip	—	Pennsylvania	—
92	$3\frac{3}{4} \times 2\frac{3}{4}$	G. L. Molesworth	—	Calcutta	—
93	6×4	R. Moody	June 6, 1889	London	—
94–96	Various	C. Mousette	—	Auteuil	—
97–106	„	A. W. Nicholls	—	Peterborough	—
107	$6\frac{1}{4} \times 4\frac{3}{4}$	O. Nicholler	August 12, 1890	Vevey	—
108–112	Various	G. J. Ninnies	—	Balham	—
113–115	6×4	Dr. H. G. Pippard	—	Connecticut	—
116–119	$3\frac{3}{4} \times 2\frac{3}{4}$	J. Porter	June 6, 1889	Sydenham	—
120	$5\frac{1}{2} \times 3\frac{1}{2}$	Dr. Puddicombe	November 14, 1884	At sea	—
121	$5\frac{1}{2} \times 4$	Dr. A. Riggenbach	—	Basle	—
122	6×4	J. Robinson	—	Regent Street	—
123	$6\frac{1}{4} \times 4\frac{3}{4}$	Rev. A. Rose	June 6, 1889	Cambridge	Bright flash. Reversed branches.
124–128	6×4	H. C. Russell, F.R.S.	—	Sydney, N.S.W.	—
129–130	6×4	A. Scrivener	June 6, 1889	Southgate, N.	—
131–141	$4\frac{1}{2} \times 3\frac{3}{4}$	E. S. Shepherd	1887, 1889	Bayswater	—
142–144	Various	W. Shuter	August 17, 1887	Belsize Park	—
145	$3\frac{1}{2} \times 2\frac{1}{4}$	G. H. Speight	June 6, 1889	Peckham	—
146	$5\frac{3}{4} \times 3\frac{3}{4}$	J. Stabb	„	Bayswater	—
147	$4 \times 2\frac{3}{4}$	R. T. Stokes	„	Long Ditton	—
148	4×3	Captain A. S. Thomson	August 17, 1887	Highbury	—
149	$4\frac{1}{2} \times 3\frac{1}{2}$	J. L. Treadway	June 6, 1889	Crouch End, N.	—
150	$8\frac{3}{4} \times 6\frac{1}{4}$	E. L. Trouvelot	1888	Meudon, near Paris	—
151–154	$4 \times 2\frac{3}{4}$	Colonel Tupman	June 6, 1889	Blackheath	—
155	$5\frac{3}{4} \times 4$	E. B. Vignoles and H. Schleusner	—	Tours	—
156–157	$4 \times 2\frac{3}{4}$	Professor Weber	—	Berlin	—
158–160	$3 \times 2\frac{1}{2}$	G. M. Whipple	June 6, 1889	Richmond	—

161	$6 \times 4\frac{1}{4}$	C. H. Wardingham . .	August 17, 1887	Wandsworth . .	—
162	$2\frac{1}{4} \times 1\frac{3}{4}$	Captain D. Wilson-Barker	—	Massowah . .	—
163	$4\frac{3}{4} \times 4$	J. W. Young . . .	June 6, 1889	Croydon . . .	—
164–167	Various	Anonymous . . .	—	—	—

CLASS C.m.—*Damage by Lightning.*

1	8×6	Lord Brabrooke . .	June 22, 1888	Audley End . .	Shivered oak.
2–5	8×6	F. Holmes . . .	July 22, 1891	Thornbury, Gloucester	„ „
6–7	$6 \times 4\frac{1}{4}$	Admiral J. P. Maclear .	June 7, 1889	Sachell Court . .	Oak tree split on June 6, shivered June 7.
8–11	$5\frac{3}{4} \times 4$	„ „ .	„	Cranleigh . . .	Trees struck.
12	$3\frac{1}{2} \times 2\frac{1}{4}$	W. Marriott . . .	March, 1888	Westminster . .	Man's clothes torn off from his body by lightning, June 8, 1878, near Ashford.
13	$3\frac{1}{2} \times 2\frac{1}{4}$	„ „ . . .	July, 1888	Hampstead . .	Clothes of two men struck at Hampstead, June 14, 1888.
14	$3\frac{1}{2} \times 2\frac{1}{4}$	„ „ . . .	June, 1888	Westminster . .	Looking-glass struck at Sunderland, September 29, 1887.
15–16	$6 \times 4\frac{1}{4}$	G. M. Whipple . .	June 6, 1889	Richmond . .	Cedar tree.
17	$6\frac{1}{4} \times 4\frac{1}{2}$	—	—	„	Tree.

CLASS D.m.—*Damage by Storms.*

1–31	Stereo	W. T. Stallings . .	June 17, 1882	Grinnell, Iowa . .	Series showing the havoc wrought by a tornado.
32–45	$7\frac{1}{2} \times 4\frac{1}{2}$	C. A. Tenney . . .	August 21, 1883	Rochester, Minn. .	„ „
46–47	Stereo	Elmer and Tenney . .	„	„ „ .	„ „
48–59	$4\frac{1}{2} \times 3\frac{3}{4}$	—	July 26, 1890	Lawrence, Mass. .	„ „
60–61	$8\frac{1}{4} \times 6$	C. Bayliss . . .	January 27, 1889	Sydney, N.S.W. .	House destroyed by wind.
62–67	$6 \times 4\frac{1}{2}$	G. Herbert . . .	November 30, 1872	Newbottle, near Banbury	Track of a whirlwind.
68–73	$8\frac{1}{2} \times 6\frac{1}{2}$	J. S. Johnston . .	September, 1889	Coney Islands . .	Atlantic rollers during the Cape Hatteras cyclone.
74–87	$9\frac{1}{2} \times 7\frac{1}{4}$	Pach Bros. . . .	„	Seabreak, Low Moor, N.J.	Other effects of the same storm.

PHOTOGRAPHS IN THE POSSESSION OF THE ROYAL METEOROLOGICAL SOCIETY—*continued.*

Regd. No.	Size	By whom taken	When	Where	Remarks
		CLASS E.m.—*Electric Sparks.*			
	Inches				
1–3	$3 \times 2\frac{1}{4}$	Shelford Bidwell, F.R.S.	1889	Wandsworth . .	Photos confirming Clayden's explanation of the 'dark' flashes of lightning.
4	--	A. W. Clayden . .	,,	Tulse Hill Park .	Set of 11 photos explaining dark images of lightning flashes.
5	—	A. W. Cramp . . .	—	—	Photos of Wimshurst machine sparks.
6–7	$6 \times 4\frac{1}{4}$	H. Schleusner and E. B. Vignoles	—	—	High and low tension discharges from Holtz machine.
8	$6 \times 4\frac{1}{2}$	A. H. Vernon . . .	—	—	Sparks from Wimshurst machine.
9	$3\frac{1}{2} \times 2\frac{1}{4}$	J. Wimshurst . . .	—	Clapham . . .	,, ,,
		CLASS F.m.—*Snowfall, &c.*			
1–2	$7\frac{3}{4} \times 4\frac{3}{4}$	B. Coolidge . . .	—	Boston, U.S.A. . .	Snow scenes.
3–6	$8\frac{1}{4} \times 6$	— Langhill . . .	March 14, 1888	New York . .	Madison Avenue in the blizzard.
7–9	6×4	E. J. Lowe, F.R.S. . .	March, 1891	Shirenewton Hall .	The blizzard of 1891 — its effects.
10	$6\frac{1}{4} \times 4\frac{1}{2}$	Dr. Riggenbach . .	1891	Switzerland . .	Snow scenes.
11	6×4	Rev. T. Smith . .	January 17, 1881	Northumberland .	,, taken by moonlight.
12	$8\frac{1}{4} \times 6\frac{1}{4}$	—	—	United States . .	,, ,,
		CLASS H.m.—*Hoar-frost.*			
1	$5\frac{1}{2} \times 4$	Beilby & Sons . .	December 22, 1891	Driffield . . .	Climatological station with thick rime.
2	$9\frac{3}{4} \times 7\frac{3}{4}$	G. Carden . .	December 15, 1890	Beddington .	—

3–4	$11\frac{1}{4} \times 9\frac{1}{4}$	G. Hadley . . .	January 7, 1889	Lincoln . . .	Thick rime on trees.
5–13	$5\frac{1}{2} \times 4$	Dr. Plowright . .	„	Near King's Lynn .	Trees broken by heavy rime.
14–15	$6\frac{1}{4} \times 4\frac{1}{2}$	Dr. A. Riggenbach . .	1891	Switzerland . .	Rime on trees.

CLASS I.m.—*Instruments.*

Sixty-seven photographs showing a variety of meteorological instruments.

CLASS K.m.

1–5	$11\frac{1}{2} \times 7$	T. Binnet & Sons . .	May, 1886	Near Worcester .	Showing flood on Severn.
6–7	$6 \times 4\frac{1}{2}$	—	„	Rotherham . .	Flooded railway station.
8–18	8×6	H. C. Russell, F.R.S. .	—	Bourke, N.S.W. .	Series showing River Darling in drought and flood.
19–24	$7\frac{1}{2} \times 5\frac{1}{2}$	„ „ .	—	Lake George, N.S.W.	—

CLASS L.m.—*Fog.*

1	$17\frac{1}{2} \times 8\frac{1}{2}$	Norman May & Co. .	January 12, 1888	Top of Worcestershire Beacon	Fog-covered country — views taken in bright sunshine above the fog.
2	$10\frac{1}{2} \times 8\frac{3}{4}$	„ „ .	„	„ „	„ „
3	$5\frac{1}{4} \times 4\frac{1}{4}$	G. W. Ormerod . .	May 8, 1882	Teignmouth . .	The 'Larry,' a land fog.
4	$6 \times 4\frac{1}{4}$	„ „ . .	October 9, 1882	„ . .	„ excessive.
5	$6\frac{1}{4} \times 4\frac{1}{4}$	„ „ . .	October 25, 1882	„ . .	„ average density.

CLASS S.m.

Forty single photographs showing the situation or surroundings of meteorological stations.
Two albums showing the position of the instruments at the stations of the Royal Meteorological Society.

Photographs in the Possession of Mr. G. J. Symons, *F.R.S., and not included in the foregoing Lists.*

Regd. No.	Size	By whom taken	When	Where	Remarks
			Lightning Flashes.		
	Inches				
1	3×2	H. J. A.	September 2, 1889	Beckenham . .	—
2	$5\frac{3}{4} \times 4$	—	—	U.S.A. . . .	—
3	$6\frac{1}{4} \times 4\frac{1}{2}$	Paul Liebich . . .	Aug. 6, 1890, 9.45 P.M.	Waldenburg, Silesia .	—
31	$8\frac{1}{2} \times 6\frac{5}{8}$	—	—	—	View of Borrowdale from the Stye.
32	$10\frac{1}{2} \times 8\frac{1}{2}$	—	—	—	Head of Borrowdale, showing position of Seathwaite and the Stye.
			Damage by Lightning.		
61	$2\frac{1}{4} \times 1\frac{3}{4}$	—	July 5, 1877	Kilburn . . .	Imaginary thunderbolt—really a clinker.
62	$2\frac{7}{8} \times 2\frac{1}{8}$	—	August 2, 1879	Wells, Norfolk . .	Church set on fire.
63	4×1	Negretti & Zambra .	May 28, 1879	Upwood Gorse, Caterham	Portions of Spratt's lightning conductor fused.
64	$5\frac{7}{8} \times 4\frac{1}{8}$	—	,,	,, ,,	,, ,,
65	$4\frac{3}{4} \times 3\frac{7}{8}$	Bruce . . .	June 9, 1883	Duns, N.B. . .	Boy's arm, showing extravasation by lightning.
66	$4 \times 3\frac{5}{8}$	J. Laing, Shrewsbury .	July, 1879	Atcham Church .	Children's boots destroyed while being worn.
67	$5\frac{7}{8} \times 4\frac{1}{8}$	—	May 20, 1887	East Tisted, Hants .	Oak shattered by lightning—east view.
68	$5\frac{7}{8} \times 4\frac{1}{8}$	—	,,	,, ,, .	Oak shattered by lightning—west view.
69	8×6	—	August 6, 1885	Richmond Park, Surrey	Oak shattered by lightning.
70	$8\frac{1}{8} \times 6$	—	,,	,, ,,	,, ,,
71	$8\frac{1}{4} \times 6\frac{3}{8}$	W. Hugo . . .	,,	,, ,,	,, ,,
72	$8\frac{1}{4} \times 6\frac{3}{8}$	,, . .	,,	,, ,,	,, ,,
73	$8\frac{5}{8} \times 6\frac{1}{4}$	—	July 6, 1881	St. John's Lodge, Regent's Park	Large poplar shattered by lightning.

91	$3\frac{5}{8} \times 2\frac{1}{4}$	J. Cox	—	Hadfield . . .	James Sidebottom's rain and snow gauge.
92	$3\frac{5}{8} \times 2\frac{1}{4}$	—	—	—	E. T. Loseby's aneroid, No. 40, 1862.
93	$5\frac{1}{2} \times 4\frac{3}{5}$	—	—	Stanley, Falkland Isles	Anemometer and thermometer stand.
96	6×4	—	—	Boston Reservoir, Rotherham	Experimental rain-gauges.
98	$5\frac{7}{8} \times 4\frac{1}{8}$	—	—	,, ,,	Experimental rain-gauges—inclined revolving gauge, 45°, side elevation.
99	$5\frac{7}{8} \times 4\frac{1}{8}$	—	—	,, ,,	Experimental rain-gauges—inclined revolving gauge, 45°, back elevation.
103	$4\frac{1}{2} \times 3\frac{1}{2}$	—	—	Castle House, Calne .	Experimental rain-gauges.
104	8×6	—	—	Sydney Observatory .	Mercurial barograph.
105	$8 \times 5\frac{3}{4}$	—	—	,, ,,	Recording parts of anemometer and pluviometer.
106	8×6	—	—	New South Wales .	Recording anemometer for country stations.
107	$10\frac{3}{8} \times 8\frac{1}{8}$	—	—	Lisbon Observatory .	Anemometer.
108	$9\frac{5}{8} \times 7\frac{1}{4}$	—	—	Strathfield Turgiss, Hants	Experimental rain-gauges.
109	$9\frac{5}{8} \times 7\frac{1}{4}$	—	—	,, ,,	Experimental rain-gauges—thermometer stands, looking north-east.
110	$9\frac{5}{8} \times 7\frac{1}{4}$	—	—	,, ,,	Experimental rain-gauges—thermometer stands, looking south-west.
111	$11\frac{1}{2} \times 9\frac{1}{8}$	F. N. Broderick, jun., Ryde	—	Ulley Reservoir, Rotherham	Rain-gauge experiments.
112	$11\frac{1}{4} \times 9$	,, ,,	—	,, ,,	,, ,,
113	$11\frac{3}{4} \times 9$	,, ,,	—	,, ,,	,, ,,
114	$12 \times 9\frac{1}{4}$	—	—	Midland Institute, Birmingham	Osler's anemometer.
115	$10\frac{1}{2} \times 8\frac{3}{4}$	—	—	I.C.I., Gt. George St., S.W.	Exhibition of anemometers by the Meteorological Society.

PHOTOGRAPHS IN THE POSSESSION OF MR. G. J. SYMONS, F.R.S.—*continued.*

Regd. No.	Size	By whom taken	When	Where	Remarks
			Frost Effects.		
	Inches				
121	6 × 4	—	—	Holland House, Kensington	Cedar grove.
122	6 × 4	—	—	Holland House, The North Lawn	Cedar tree.
123	6 × 4	—	—	Holland House . .	View in flower garden.
124	$6\frac{1}{8} \times 4$	—	—	Hampstead . .	Araucaria.
125	$6\frac{5}{8} \times 4\frac{3}{8}$	Geo. Corden, F.R.Met. Soc., Croydon	December 15, 1890	Beddington . .	Church and churchyard.
126	—	—	—	—	At Royal Meteorological Society.
127	$8 \times 5\frac{1}{4}$	—	March, 1891	Lyme Regis . .	Snow-drift.
128	$8 \times 5\frac{3}{8}$	—	,,	,,	,,
129	$6\frac{3}{8} \times 4\frac{1}{2}$	—	—	York	The Ouse.
130	$9\frac{1}{4} \times 7\frac{1}{4}$	—	January 25, 1881	Hawes . . .	Hardraw Scar in winter.
131	$8\frac{1}{2} \times 6\frac{1}{2}$	—	—	,,	,, ,, summer.
132	$9\frac{1}{4} \times 7\frac{1}{4}$	—	January 22, 1881	Whitfield . . .	The Fell.
133	$8 \times 6\frac{1}{8}$	—	February 10, 1887	Aysgarth . . .	Icicles near Middle Force.
134	8 × 6	F. W. Stow . . .	January, 1891	,,	Upper Force.
			Damage by Wind.		
151	$8\frac{1}{2} \times 6\frac{1}{4}$	—	October 24, 1878	Walmer, Kent . .	Back of Walmer Court, looking south.
152	$8\frac{1}{4} \times 6\frac{1}{2}$	—	,,	,, ,,	Back of Walmer Court, looking east.
153	$8\frac{3}{8} \times 6\frac{3}{8}$	—	,,	,, ,,	Back of Walmer Court, looking north-east.
154	$8\frac{2}{8} \times 6\frac{3}{8}$	—	,,	,, ,,	Cambridge Road and Terrace, looking south-east.
155	$8\frac{1}{4} \times 6\frac{5}{8}$	—	,,	,, ,,	Ely House and Palmerston Villa, looking east.

156	$7\frac{3}{4} \times 5\frac{1}{4}$	F. N. Broderick, jun. Ryde		September 28, 1876	Isle of Wight, The Parade, Cowes	In the track of the tornado—houses wrecked.
157	$7\frac{7}{8} \times 5\frac{1}{4}$	,,	,,	,,	Isle of Wight, near Cowes	In the track of the tornado—ruins of cottage.
158	$8 \times 5\frac{1}{2}$	,,	,,	,,	,, ,,	In the track of the tornado—tree shattered.
159	$8\frac{1}{8} \times 5\frac{1}{2}$	,,	,,	,,	,, ,,	,, ,,
160	$8\frac{1}{4} \times 5\frac{1}{2}$	,,	,,	,,	,, ,,	,, ,,
161	$7\frac{1}{2} \times 5$	,,	,,	,,	Isle of Wight, Ruffin's Copse, near Cowes	In the track of the tornado—trees blown down.
162	$8 \times 5\frac{1}{2}$	,,	,,	,,	Isle of Wight, in a copse near Cowes	In the track of the tornado—trees shattered.
163	$7\frac{7}{8} \times 5\frac{3}{8}$	,,	,,	,,	Isle of Wight . .	In the track of the tornado—trees broken at top.
164	$11\frac{3}{8} \times 9\frac{1}{4}$	—		July 31, 1881	Bramham Park . .	Trees overthrown.
165	$9\frac{1}{2} \times 7\frac{1}{2}$	—		,,	,,	Stable wrecked by falling trees.
166	$9\frac{1}{2} \times 7\frac{1}{2}$	—		,,	,,	,, ,,
167	$9\frac{3}{8} \times 7$	—		June 12, 1875	Baldock . . .	Maltings wrecked.
168	$9\frac{1}{2} \times 7\frac{1}{8}$	—		,,	,,	,,
169	$9\frac{1}{2} \times 7\frac{3}{8}$	—		,,	,,	,,
170	$3\frac{5}{8} \times 3\frac{1}{2}$	—		August 18, 1890	Dreux, France . .	General view of town after tornado.
171	$3\frac{5}{8} \times 3\frac{1}{2}$	—		,,	,, ,,	Houses unroofed, &c.
172	$3\frac{5}{8} \times 3\frac{1}{2}$	—		,,	,, ,,	House wrecked.
173	$3\frac{5}{8} \times 3\frac{1}{2}$	—		,,	,, ,,	,,
174	$6\frac{3}{4} \times 5$	—		,,	,, ,,	,,
175	$6\frac{7}{8} \times 4\frac{7}{8}$	—		,,	,, ,,	,,
176	7×5	—		,,	Dreux, France, Maison des Communes	,,
177	$3\frac{1}{2} \times 3\frac{1}{2}$	—		,,	Dreux, France . .	Ruins of military storehouse
178	$3\frac{1}{2} \times 3\frac{1}{2}$	—		,,	,, ,,	Tree broken.
179	$3\frac{1}{2} \times 3\frac{1}{2}$	—		,,	,, ,,	Ruins of houses.
180	$7 \times 4\frac{7}{8}$	—		,,	,, ,,	Maison Vivien.
180*a*	$6\frac{1}{2} \times 4\frac{5}{8}$	—		,,	,, ,,	Ruins of house.
180*b*	$6\frac{3}{8} \times 4\frac{7}{8}$	—		,,	,, ,,	Trees overthrown, windows broken.

PHOTOGRAPHS IN THE POSSESSION OF MR. G. J. SYMONS, F.R.S.—*continued.*

Regd. No.	Size	By whom taken	When	Where	Remarks
			Effects o Floods.		
	Inches				
181	$5\frac{1}{4} \times 4\frac{1}{4}$	—	July 9, 1870	Todmorden . .	Bottom of Green's Clough.
182	$5\frac{5}{8} \times 4\frac{1}{4}$	—	,,	,,	Ruins of Portsmouth Mill.
183	$3\frac{1}{2} \times 2\frac{1}{4}$	—	August 2, 1888	Chelmsford, Essex .	The great flood—eleven different photos.
184	$5\frac{1}{4} \times 4\frac{1}{8}$	T. H. Mower, Clare Street, Bristol	March 9, 1889	Bristol . . .	The great flood—four different photos.
185	$1\frac{7}{8} \times 1\frac{3}{8}$	,, ,,	,,	,,	The great flood—six different photos.
186	$5\frac{5}{8} \times 4\frac{1}{8}$	A. E. Smith & Co. . .	,,	,,	The great flood.
187	$5\frac{1}{2} \times 4$	,, ,, . .	,,	,,	,, —three different photos.
188	$5\frac{5}{8} \times 4$	—	June, 1889	Chetnole, near Batcombe, Dorset	Damage by flood.
189	$7\frac{1}{3} \times 5\frac{1}{2}$	—	—	Hereford . . .	View at railway station.
190	$8\frac{1}{8} \times 6$	—	May 25, 1890	Lyme Regis . .	Parapet of bridge washed away &c.—three different photos.
191	8×6	—	November 28, 1888	Aysgarth . . .	Middle Force—a winter flood.
192	8×6	—	July 26, 1888	,,	,, a summer flood.
193	$8\frac{1}{8} \times 5\frac{3}{8}$	—	June 25, 1888	Coleford, Gloucestershire	Débris deposited on a gentleman's lawn—two different photos.
			Meteorological Observatories.		
211	$3\frac{1}{2} \times 2\frac{3}{4}$ to $11\frac{1}{2} \times 7\frac{1}{2}$	Various photographers .	1888–1889	Ben Nevis, N.B. .	Eighteen photos of the Observatory, some showing the effects of hoar-frost.
213	$10\frac{1}{4} \times 7\frac{3}{4}$ to $14 \times 10\frac{1}{4}$	—	1877–1885	Pic du Midi de Bigorre, France	Eight photos of the Observatory.

Twelfth Report of the Committee, consisting of the Rt. Hon. Lord KELVIN, Mr. R. ETHERIDGE, Professor JOHN PERRY, Dr. HENRY WOODWARD, Professor THOMAS GRAY, *and* Professor JOHN MILNE (*Secretary*), *appointed for the purpose of investigating the Earthquake and Volcanic Phenomena of Japan.* (*Drawn up by the Secretary.*)

THE GRAY-MILNE SEISMOGRAPH.

THE first of the above seismographs, constructed in 1883, partly at the expense of the British Association, still continues to be used as the standard instrument at the Central Observatory in Tokio. I am indebted to Mr. K. Kobayashi, the Director of the Observatory, for the following table of its records :—

Catalogue of Earthquakes recorded at the Central Meteorological Observatory between May 1891 *and April* 30, 1892.

No.	Month	Date	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			1891.							
			H. M. S.	M. S.						
1,106	V.	5	8 16 48 A.M.	2 30	S.S.E.–N.N.W.	1·3	0·6	—	—	slow
1,107	„	9	9 51 38 A.M.	—	—	very slight		—	—	—
1,108	„	14	4 13 39 P.M.	0 20	E.–W.	slight		—	—	slow
1,109	„	18	9 40 52 A.M.	—	—	very slight		—	—	—
1,110	„	„	10 53 39 A.M.	—	—	very slight		—	—	—
1,111	„	„	11 21 22 A.M.	—	—	slight		—	—	—
1,112	„	19	0 0 15 P.M.	4 40	E.S.E.–W.N.W.	1·3	0·5	slight		slow
1,113	„	25	1 37 44 P.M.	1 20	W.S.W.–E.N.E.	0·7	0·3	—	—	„
1,114	„	26	0 19 55 P.M.	—	—	very slight		—	—	—
1,115	„	30	2 20 19 P.M.	1 30	W.N.W.–E.S.E.	0·9	0·55	slight		slow
1,116	VI.	1	10 11 0 A.M.	—	—	very slight		—	—	—
1,117	„	„	0 38 43 P.M.	1 23	S.–N.	0·7	0·4	slight		quick
1,118	„	4	9 22 13 P.M.	1 30	W.S.W.–E.N.E.	0·8	0·3	slight		„
1,119	„	„	11 19 15 P.M.	0 50	N.E.–S.W.	0·6	0·35	—	—	„
1,120	„	19	6 41 49 A.M.	1 10	E.S.E.–W.N.W.	0·4	0·5	—	—	„
1,121	„	22	9 43 42 A.M.	—	—	slight		—	—	—
1,122	„	25	3 41 48 A.M.	4 30	N.N.W.–S.S.E.	1·0	0·9	slight		slow
1,123	VII.	6	11 2 28 A.M.	—	—	very slight		—	—	—
1,124	„	„	1 38 11 P.M.	—	—	very slight		—	—	—
1,125	„	7	0 6 12 P.M.	7 30	S.S.W.–N.N.E.	2·9	1·4	slight		slow
1,126	„	15	9 18 0 A.M.	—	—	slight		—	—	—
1,127	„	„	2 21 58 P.M.	—	—	slight		—	—	—
1,128	„	19	5 57 30 P.M.	1 20	N.E.–S.W.	1·0	1·0	slight		slow
1,129	„	21	8 19 20 P.M.	6 0	S.W.–N.E.	3·6	10·5	0·3	0·5	„
1,130	„	24	6 15 35 A.M.	—	—	feeble		—	—	—
1,131	VIII.	4	4 40 21 A.M.	1 30	S.E.–N.W.	0·2	0·5	slight		quick
1,132	„	5	8 14 50 A.M.	0 38	S.–N.	0·7	0·4	—	—	slow
1,133	„	21	0 26 8 P.M.	0 45	E.N.E.–W.S.W.	0·1	0·2	slight		quick
1,134	„	24	9 44 10 P.M.	—	—	—	—	—	—	—
1,135	IX.	3	2 11 23 P.M.	0 30	S.–N.	slight		—	—	slow
1,136	„	8	10 49 25 A.M.	1 30	E.S.E.–W.N.W.	0·8	0·6	—	—	quick
1,137	„	9	11 49 58 A.M.	—	—	—	—	—	—	—
1,138	„	18	8 46 9 A.M.	0 30	S.–N.	slight		—	—	slow
1,139	X.	4	6 28 38 P.M.	1 0	S.W.–N.E.	0·6	0·4	slight		quick
1,140	„	5	8 10 23 P.M.	1 30	W.S.W.–E.N.E.	0·8	0·5	slight		slow
1,141	„	6	1 1 27 A.M.	—	—	slight		—	—	—

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Date	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,142	X.	6	6 47 30 A.M.	1 50	S.–N.	0·2	0·2	slight		slow
1,143	„	„	2 19 2 P.M.	0 40	—	—	—	—	—	—
1,144	„	7	11 23 47 A.M.	1 0	S.–N.	1·2	0·2	—	—	very slow
1,145	„	8	9 0 34 A.M.	—	—	slight		—	—	—
1,146	„	11	4 16 27 P.M.	2 30	S.E.–N.W.	2·0	2·0	0·2	0·6	quick
1,147	„	12	2 7 28 P.M.	—	—	slight		—	—	—
1,148	„	„	5 28 17 P.M.	—	—	slight		—	—	—
1,149	„	„	9 31 40 P.M.	1 0	E.S.E.–W.N.W.	0·3	0·2	—	—	quick
1,150	„	16	7 4 15 A.M.	—	—	slight		—	—	—
1,151	„	22	6 26 20 A.M.	1 20	E.S.E.–W.N.W.	1·1	1·3	slight		quick
1,152	„	„	9 0 5 P.M.	1 0	N.W.–S.E.	0·4	0·3	—	—	slow
1,153	„	24	8 17 49 P.M.	1 25	S.–N.	1·0	0·3	—	—	„
1,154	„	27	6 16 13 A.M.	2 10	E.S.E.–W.N.W.	0·8	0·9	slight		quick
1,155	„	„	7 9 45 P.M.	1 10	E.S.E.–W.N.W.	0·7	0·5	—	—	slow
1,156	„	28	6 39 11 A.M.	7 0	E.–W.	2·4	31·5	2·4	4·5	„
1,157	„	„	7 3 40 A.M.	—	—	slight		—	—	—
1,158	„	„	7 6 46 A.M.	—	—	slight		—	—	—
1,159	„	„	7 21 32 A.M.	—	—	slight		—	—	—
1,160	„	„	7 25 23 A.M.	—	—	slight		—	—	—
1,161	„	„	7 49 59 A.M.	1 13	S.–N.	0·7	0·2	—	—	slow
1,162	„	„	7 54 47 A.M.	1 30	S.S.E.–N.N.W.	1·0	0·6	—	—	„
1,163	„	„	9 9 42 A.M.	—	—	slight		—	—	—
1,164	„	„	10 38 11 A.M.	3 0	S.S.W.–N.N.E.	2·0	0·7	—	—	slow
1,165	„	„	11 29 19 A.M.	2 0	S.–N.	1·1	0·3	—	—	„
1,166	„	„	11 58 22 A.M.	—	—	slight		—	—	—
1,167	„	„	0 12 6 P.M.	—	—	slight		—	—	—
1,168	„	„	1 3 19 P.M.	—	—	slight		—	—	—
1,169	„	„	3 3 57 P.M.	—	—	slight		—	—	—
1,170	„	„	3 27 0 P.M.	—	—	slight		—	—	—
1,171	„	„	3 33 47 P.M.	—	—	slight		—	—	—
1,172	„	„	3 57 11 P.M.	—	—	slight		—	—	—
1,173	„	„	5 32 28 P.M.	1 50	S.E.–N.W.	0·9	0·6	—	—	slow
1,174	„	„	6 12 32 P.M.	—	—	slight		—	—	—
1,175	„	„	7 15 37 P.M.	—	—	slight		—	—	—
1,176	„	„	7 28 25 P.M.	1 30	S.–N.	0·5	0·2	—	—	slow
1,177	„	„	8 25 10 P.M.	1 10	S.–N.	0·7	0·2	—	—	„
1,178	„	29	7 8 31 A.M.	—	—	slight		—	—	—
1,179	„	30	0 15 14 A.M.	2 30	S.–N.	1·2	0·7	—	—	slow
1,180	„	„	2 27 47 A.M.	1 30	S.–N.	1·1	0·4	—	—	„
1,181	„	„	2 25 56 P.M.	0 30	E.–W.	slight		—	—	„
1,182	„	„	7 9 7 P.M.	0 35	S.–N.	slight		—	—	„
1,183	„	„	10 32 25 P.M.	—	—	slight		—	—	—
1,184	XI.	1	6 2 29 A.M.	—	—	slight		—	—	—
1,185	„	„	9 20 6 P.M.	1 0	S.W.–N.E.	0·6	0·3	—	—	slow
1,186	„	2	4 59 23 P.M.	1 10	S S.E.–N.N.W.	0·8	0·2	—	—	„
1,187	„	5	1 2 18 P.M.	—	—	slight		—	—	—
1,188	„	6	10 0 14 A.M.	1 0	E.–W.	0·6	0·2	—	—	slow
1,189	„	7	2 18 5 A.M.	3 0	S.–N.	1·8	0·4	—	—	„
1,190	„	„	3 36 54 P.M.	2 30	N.W.–S.E.	0·5	0·3	slight		quick
1,191	„	20	9 45 26 P.M.	1 20	S.W.–N.E.	0·8	0·2	—	—	slow
1,192	„	23	0 30 11 A.M.	1 30	S.E.–N.W.	0·5	1·0	slight		quick
1,193	„	„	2 39 45 A.M.	—	—	slight		—	—	—
1,194	„	28	9 41 4 A.M.	1 30	E.–W.	1·1	0·2	—	—	slow
1,195	„	„	11 9 36 A.M.	1 0	E.–W.	slight		—	—	„
1,196	XII.	3	2 2 27 A.M.	1 0	S.–N.	0·9	0·2	—	—	„
1,197	„	„	1 11 54 P.M.	—	—	—	—	—	—	—
1,198	„	„	9 51 15 P.M.	—	—	very slight		—	—	—
1,199	„	4	9 29 4 P.M.	1 30	N.W.–S.E.	0·8	0·4	—	—	slow
1,200	„	8	4 2 17 P.M.	—	—	—	—	—	—	—
1,201	„	11	8 44 4 P.M.	1 0	S.W.–N.E.	0·7	0·3	slight		quick
1,202	„	15	11 23 45 P.M.	2 50	E.S.E.–W.N.W.	0·8	0·9	slight		very quick
1,203	„	21	2 20 15 P.M.	—	—	slight		—	—	—
1,204	„	22	4 23 38 A.M.	—	—	very slight		—	—	—
1,205	„	24	5 33 14 A.M.	3 40	N.W.–S.E.	1·9	16·2	0·9	2·0	quick
1,206	„	„	5 52 22 A.M.	—	—	slight		—	—	—
1,207	„	„	6 26 16 A.M.	—	—	slight		—	—	—

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Date	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,208	XII.	25	7 38 13 P.M.	1 0	N.W.–S.E.	0·7	0·3	—	—	slow
1,209	„	26	10 22 37 P.M.	1 0	S.E.–N.W.	0·9	0·2	—	—	„
1,210	„	29	11 13 20 P.M.	—	—	—	—	—	—	—
					1892.					
1,211	I.	3	4 22 9 P.M.	2 0	S.W.–N.E.	0·8	0·3	—	—	slow
1,212	„	4	10 10 31 A.M.	1 20	S.–N.	0·7	0·3	—	—	„
1,213	„	6	2 53 36 A.M.	1 20	N.W.–S.E.	0·8	0·2	—	—	„
1,214	„	13	10 48 27 A.M.	—	—	slight		—	—	—
1,215	„	17	3 29 8 A.M.	0 50	S.S.W.–N.N.E.	0·8	0·5	—	—	slow
1,216	„	„	11 35 12 P.M.	2 40	E.S.E.–W.N.W.	0·8	2·4	0·6	0·2	very quick
1,217	„	24	9 59 2 A.M.	—	—	slight		—	—	—
1,218	„	28	11 20 10 P.M.	0 50	N.E.–S.W.	0·8	0·3	—	—	slow
1,219	„	31	10 23 16 A.M.	1 40	E.S.E.–W.N.W.	0·8	1·6	0·2	0·2	very quick
1,220	II.	2	9 22 9 P.M.	0 40	S.–N.	0·6	0·2	—	—	slow
1,221	„	3	6 53 39 P.M.	2 0	S.E.–N.W.	0·4	0·7	slight		„
1,222	„	12	7 21 18 A.M.	—	—	slight		—	—	—
1,223	„	„	0 38 35 P.M.	—	—	slight		—	—	—
1,224	„	15	3 20 35 A.M.	—	—	slight		—	—	—
1,225	„	17	11 0 53 A.M.	—	—	slight		—	—	—
1,226	„	„	9 41 58 P.M.	—	—	slight		—	—	—
1,227	„	18	0 59 33 P.M.	—	—	slight		—	—	—
1,228	„	20	2 39 43 A.M.	—	—	slight		—	—	—
1,229	„	21	3 49 52 A.M.	2 0	S.W.–N.E.	0·8	0·5	slight		quick
1,230	„	29	3 38 31 A.M.	—	—	slight		—	—	—
1,231	III.	8	8 7 19 P.M.	—	—	slight		—	—	—
1,232	„	9	2 24 25 P.M.	—	—	slight		—	—	—
1,233	„	22	5 42 53 A.M.	—	—	slight		—	—	—
1,234	IV.	2	0 35 23 A.M.	1 20	W.S.W.–E.N.E.	0·2	0·3	slight		quick
1,235	„	3	3 18 15 A.M.	1 20	S.W.–N.E.	0·2	0·4	0·2	0·2	slow
1,236	„	13	4 13 0 A.M.	0 50	S.–N.	0·8	0·4	—	—	quick
1,237	„	19	6 54 1 A.M.	1 0	E.–W.	0·1	0·2	—	—	„
1,238	„	22	1 26 46 A.M.	1 30	S.–N.	0·2	0·4	slight		„
1,239	„	24	0 41 8 A.M.	—	—	slight		—	—	—
1,240	„	30	5 59 57 A.M.	—	—	slight		—	—	—

THE EARTHQUAKES OF 1888 AND 1889.

In my fourth Report to the British Association I gave an account of 387 earthquakes which had been recorded in North Japan between October 1881 and October 1883. In the sixth, eighth, and tenth Reports accounts are given of the earthquakes felt throughout the whole Empire of Japan during the years 1885, 1886, and 1887. The records of these disturbances were obtained from some 700 observing stations under the control of the Central Meteorological Bureau. Through the kindness of the director of this bureau, Mr. K. Kobayashi, I am now able to give to the Association an epitome of the observations for 1888 and 1889.

I. *Earthquakes in* 1888.

In 1888 no less than 630 earthquakes were recorded.

1. *Number of Earthquakes in each Season.*

The following table gives the number of earthquakes recorded during each month of the year 1888:—

Month	January	February	March	April	May	June	July	August	September	October	November	December	Total	Average
Frequency	53	77	46	42	69	40	40	34	42	47	85	55	630	52·5

The maximum frequency occurred in November, while the minimum was in August. The following table gives the frequency in each season:—

Seasons	Spring (March, April, May)	Summer (June, July, August)	Autumn (September, October, November)	Winter (December, January, February)	Total	Average
Frequency . . .	157	114	174	185	630	157·5

The maximum seismic frequency occurred in winter, while the minimum was in summer. If we divide a year into the hot and cold seasons we have:—

Season	Hot (from April to September inclusive)	Cold (from October to March inclusive)	Total	Average
Frequency . . .	267	363	630	315·0

2. *Number of Earthquakes in each Hour.*

The following table shows earthquake frequency in each hour:—

Months	Hours												Total
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	
FORENOON—													
January .	3	2	3	4	1	2	—	—	3	1	1	1	21
February .	2	5	3	2	2	1	4	—	2	2	4	5	32
March . .	—	1	1	3	3	—	4	1	1	—	1	5	20
April . .	1	—	1	2	—	4	3	5	1	—	2	2	21
May . .	2	4	2	2	10	2	1	3	1	3	5	1	36
June . .	2	—	2	1	—	—	4	5	—	1	1	1	17
July . .	—	—	3	—	4	1	2	3	1	1	2	3	20
August . .	—	2	1	4	—	2	1	2	3	3	—	3	21
September .	1	2	2	1	2	5	—	2	3	1	4	2	25
October . .	2	2	3	2	3	3	3	4	1	1	2	—	26
November .	8	5	5	2	4	2	1	3	5	5	1	2	43
December .	3	5	3	4	4	5	1	2	4	1	—	1	33
Total .	24	28	29	27	33	27	24	30	25	19	23	26	

Months	Hours												Total
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	
AFTERNOON—													
January .	2	1	1	3	1	3	4	6	3	2	3	3	32
February .	4	4	3	11	2	3	4	—	2	5	1	6	45
March . .	2	—	3	5	—	3	2	5	3	2	1	—	26
April . .	1	3	5	2	3	1	—	1	—	1	2	2	21
May . .	1	—	2	2	1	3	3	5	4	6	4	2	33
June . .	3	3	3	1	1	1	—	1	1	5	3	1	23
July . .	1	2	2	3	3	2	—	2	—	2	1	2	20
August . .	—	—	1	1	1	—	1	1	—	6	2	—	13
September .	1	2	2	3	—	2	1	2	1	—	2	1	17
October . .	1	1	—	2	3	2	1	2	1	2	2	4	21
November .	5	4	4	—	7	4	3	1	6	1	2	5	42
December .	1	2	1	2	2	—	4	4	—	1	3	2	22
Total .	22	22	27	35	24	24	23	30	21	33	26	28	630

From the above we see that the greatest number of earthquakes occurred between 3–4 P.M., and the next maximum frequency between 4–5 A.M. and between 9–10 P.M.; whereas the minimum was between 9–10 A.M. and between 8–9 P.M. If we took 6 o'clock as the limit between day and night, we should have at night a greater number of earthquakes than during the day by 26.

3. *Areas of Seismic Disturbances and Intensity.*

The area shaken by an earthquake varied from a mere local tract up to an area of several thousand square ri, depending chiefly on the intensity of the shock. In the following table the number of earthquakes during the year has been classified according to the size of the area disturbed. One square ri=5·9 square miles.

Area	January	February	March	April	May	June	July	August	September	October	November	December	Total	Average
Over 1,000 square ri . . .	2	6	3	8	5	3	2	1	2	1	7	4	44	3·7
1,000–100 square ri . . .	8	15	7	2	16	9	10	8	4	6	9	10	104	8·7
Under 100 square ri . . .	43	56	36	32	48	28	28	25	36	40	69	41	482	40·2
Total . . .	53	77	46	42	69	40	40	31	42	47	85	55	630	52·5

4. *Area Shaken during each Month in Square Ri.*

January	February	March	April	May	June	July	August	September	October	November	December	Total
6,950	36,410	7,730	20,000	20,810	8,620	11,000	5,870	6,240	4,510	18,760	12,970	161,870

5. *Intensity of Earthquakes.*

Of the 630 earthquakes in the year 1888, severe earthquakes numbered 58, moderate ones 264, and feeble ones 308. Thus 9 per cent. of the

total number of earthquakes in the year were severe, 42 per cent. moderate, and 49 per cent. feeble.

Notes on Special Earthquakes.

1. On February 5, at 1 A.M., an earthquake was felt over nearly the whole of North Japan, extending from Yezo in the north to Tokio in the south. The area shaken was 9,670 square ri. This is the first time since 1884, when extended observations were commenced, that so large an area was disturbed. Whatever damage occurred was slight.

2. On April 11, at 3 A.M., an area of 2,190 square ri was shaken in Central Japan. The provinces of Tango and Tanba were most seriously affected.

3. On April 29, at 10 A.M., North Japan was disturbed by a shock extending over 1,930 square ri. In Nasu-gōri river banks gave way, at Utsonomiya walls were cracked, and to the south, in Tokio and other places, clocks were stopped and articles overturned. The motion was generally horizontal.

4. On July 15, at 7.30 A.M., an elliptical area of 600 square ri near Lake Inawashiro was suddenly shaken. This was followed by a second shaking, and whilst this continued Bandaisan, which overlooks the lake, exploded, and in a few minutes buried nearly 28 square miles of country beneath a sea of earth and boulders 30 to 100 feet in depth.

Whether the preliminary shakings were unsuccessful efforts of the steam beneath Bandaisan to obtain a vent, or whether they were shakings due to faulting or other causes, which destroyed the equilibrium between internal forces and the rocky cover which restrained them, is a matter for speculation. It may here be mentioned that one result of the Bandaisan explosion has been to form a lake which is 8½ miles long and from 1 to 3 miles in breadth.

Earthquakes Observed at the Central Observatory in Tokio in 1888.

A list of the earthquakes felt in Tokio in 1888 has been published in a previous Report. Between January and December 101 disturbances were recorded.

1. *Earthquake Frequency per Month.*

During the year 1888 the number of earthquakes in each month was as follows:—

Month	January	February	March	April	May	June	July	August	September	October	November	December	Total
Frequency	4	15	7	7	11	9	9	7	11	4	13	4	101

From the above it is seen that the maximum frequency occurred in February, and the minimum frequency in January, October, and December.

2. *Earthquake Frequency per Season.*

Year	Spring	Summer	Autumn	Winter	Average
1888	25	25	28	23	25

3. *Frequency during Hot and Cold Periods.*

Year	Hot	Cold	Average
1888	54	47	50

4. *Hourly Frequency of Earthquakes.*

The number of earthquakes in each hour during the year will be found from the following table:—

Months	Hours												Total
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	
FORENOON—													
January	—	—	—	—	—	—	—	—	1	—	—	—	1
February	1	—	1	—	—	—	—	—	—	—	1	1	4
March	—	—	—	—	1	1	1	—	—	—	—	—	3
April	—	—	—	—	—	1	1	—	1	—	1	—	4
May	—	—	—	—	3	—	—	—	—	1	1	1	6
June	1	—	—	—	—	—	1	2	—	—	—	—	4
July	—	—	1	—	1	—	—	2	—	1	—	—	5
August	—	1	—	1	—	—	—	—	—	2	—	2	6
September	1	—	1	—	1	3	—	1	1	2	—	—	10
October	—	1	—	—	—	—	1	1	—	—	—	—	3
November	3	—	1	—	1	—	—	—	1	—	—	—	6
December	—	—	—	1	1	—	—	1	—	—	—	—	3
Total	6	2	4	2	8	[illegible]	4	7	4	[illegible]	3	4	
AFTERNOON—													
January	—	—	—	—	—	1	—	—	—	—	1	—	2
February	1	1	1	5	—	—	2	—	—	—	—	1	11
March	—	—	—	1	—	—	—	1	—	1	1	—	4
April	—	—	2	—	—	—	—	—	—	—	—	1	3
May	—	—	—	—	—	—	2	1	1	—	—	1	5
June	—	—	1	1	—	—	—	—	—	2	—	1	5
July	—	—	—	1	1	1	—	—	—	1	—	—	4
August	—	—	—	—	—	—	—	—	—	1	—	—	1
September	—	1	—	—	—	1	—	—	—	—	—	—	2
October	—	—	—	—	1	—	—	—	—	—	—	—	1
November	—	3	—	—	2	1	—	—	—	—	1	—	7
December	1	—	—	—	—	—	—	—	—	—	—	—	1
Total	2	5	4	8	4	4	4	2	1	5	3	4	101

We see from the above that the maximum frequency was between 3–4 P.M. and 4–5 A.M., and the minimum between 8–9 P.M, 0–1 P.M., 7–8 P.M., 1–2 A.M., and 3–4 A.M.

5. *Intensity of Earthquakes.*

Of the 101 earthquakes which took place in Tokio in the year 1888, the following are the most notable :—

Date	Time of Occurrence	Duration
April 29	10h. 0m. 33s. A.M.	8′

Date	Horizontal Motion				Vertical Motion
	Maximum Range in mm.	Maximum Velocity in mm.	Maximum Acceleration in mm.	Direction	Maximum Amplitude in mm.
April 29 . .	5·6 in 0·8 sec.	22 in 1·0 sec.	172·8 in 1·0 sec.	S.E. to N.W.	1·5 in 0·6 sec.

The origin of this earthquake must have been somewhere in the Gulf of Tokio. In the provinces on the Gulf river banks gave way, rents were made in walls, articles fell down, liquids flowed from vessels, clocks were stopped, &c. The duration was long. The next shocks of long duration were those which occurred at 6h. 9m. 20s. P.M. on May 12, and at 8h. 13m. 33s. on November 3, each having a duration of 4½ minutes. All the remaining shocks had a duration of less than 4 minutes. There was only one earthquake which had a range greater than 10 mm., 8 earthquakes which had ranges 1–10 mm., 28 which were less than 1 mm., and the remaining 64 were so feeble that measurement was impossible.

From the preceding facts we may conclude that severe earthquakes were few in number this year, about 90 per cent. of them being feeble.

6. *Direction of Earthquakes.*

The principal directions of motion of the 101 earthquakes this year were as follows :—

Year	S. to N.	S.S.W. to N.N.E.	S.W. to N.E.	S.W.W. to N.E.E.	E. to W.	S.E.E. to N.W.W.	S.E. to N.W.	S.S.E. to N.N.W.	Unknown
1888 . . .	5	3	4	2	27		8	2	45

Earthquake motion was therefore chiefly E. to W., and after that S.E. to N.W. It occurred least in the directions S.S.E. to N.N.W., and S.W.W. to N.E.E., the next being S.S.W. to N.N.E. Besides these, there were 45 feeble earthquakes having unknown directions.

7. *Nature of Earthquakes.*

An earthquake may have a horizontal or vertical motion. And the motion may be rapid or slow. In the following table we show the nature of the earthquakes in 1888 :—

Nature	Months												Total
	January	February	March	April	May	June	July	August	September	October	November	December	
Combination of horizontal and vertical motion	1	1	—	2	1	1	1	—	1	1	2	—	11
Horizontal motion	2	12	7	3	9	8	7	4	5	—	9	3	69
Unknown	1	2	—	2	1	—	1	3	5	3	2	1	21
Rapid	1	2	4	2	1	3	—	1	2	1	4	—	21
Slow	2	10	1	2	1	2	4	2	2	—	5	3	34
Unknown	1	3	2	3	9	4	5	4	7	3	4	1	46

Thus, of 101 earthquakes, 69 were horizontal, 11 were a combination of horizontal and vertical, and 21 were not definite, being very feeble. The number of slow earthquakes exceeded that of rapid ones by 13, while 46 were so feeble that it was difficult to determine their period of vibration.

II. *Earthquakes in* 1889.

In 1889 the number of disturbances recorded in the Empire was 930. The great increase in the number of disturbances this year was due to the number of small shocks which succeeded the great earthquake of Kumamoto, which I described in the tenth Report (1890). The great earthquake took place on July 28, and on the 29th and 30th 62 shocks were recorded. Subsequently the exact time of occurrence of 281 disturbances was noted. The total number of shocks following the great earthquake was therefore 343, and the total for the Empire, 992. As in previous years, certain parts of the western side of Japan appear to have been free from earthquakes.

1. *Number of Earthquakes in each Season.*

The number of earthquakes observed every month from January to December 1889 is given in the following table:—

January	February	March	April	May	June	July	August	September	October	November	December	Total	Average
53	57	63	67	60	39	65	192	79	103	82	72	930	77·5

From the above table it will be seen that we have the maximum frequency in August, and the minimum in June. The general increase in frequency is due to repeated shocks after the terrible earthquake in Hiogo already referred to.

The frequency in each season may be deduced from the above table; thus:—

Spring	Summer	Autumn	Winter	Total	Average
190	296	264	180	930	232·5

From the preceding table we see that the average frequency per season was 232·5, and also that the maximum frequency was in summer, and the minimum in winter.

If we call the six months from April to October the hot season, and those from October to April the cold season, we have :—

Hot	Cold	Total	Average
502	428	930	465

Thus the average frequency of the two seasons was 465, and the earthquakes occurred more frequently during the hot season than in the cold one.

2. *Number of Earthquakes in each Hour.*

The occurrence of earthquakes according to the hours of the day and night is shown in the following table :—

Months	Hours												Total
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	
FORENOON—													
January	—	—	3	2	4	5	2	4	—	2	3	—	25
February	—	—	1	1	2	4	2	5	5	3	2	2	27
March	2	1	3	2	—	2	5	2	2	4	2	3	28
April	4	3	3	5	2	1	1	5	1	1	1	1	28
May	3	1	1	5	—	5	7	1	4	5	3	3	38
June	—	2	1	3	—	1	3	3	1	1	4	1	20
July	4	4	8	5	1	5	3	2	—	3	2	2	39
August	6	8	12	15	10	9	7	9	8	5	7	6	102
September	1	5	6	3	3	3	3	6	3	2	8	3	46
October	1	6	6	4	2	6	6	3	3	1	3	3	44
November	3	1	5	1	3	2	2	4	5	8	1	4	39
December	1	4	4	2	2	2	1	1	3	3	4	6	33
Total	25	35	53	48	29	45	42	45	35	38	40	34	
AFTERNOON—													
January	3	4	3	1	2	4	—	2	4	4	—	1	28
February	1	3	4	4	2	1	—	3	1	6	4	1	30
March	2	2	4	3	3	4	3	6	1	2	1	4	35
April	5	7	6	3	5	4	—	3	3	2	1	—	39
May	4	2	2	1	—	3	3	2	—	2	1	1	21
June	1	4	3	1	—	2	2	1	—	4	1	—	19
July	3	2	1	1	2	1	1	2	2	4	3	4	26
August	11	10	10	9	11	8	6	6	4	5	4	6	90
September	5	3	3	1	4	1	1	4	1	2	3	5	33
October	6	4	3	2	7	3	7	5	5	2	12	5	61
November	7	3	4	5	2	3	—	1	5	5	4	4	43
December	5	4	4	1	2	3	—	5	3	1	8	1	37
Total	53	48	47	32	40	37	23	40	29	39	42	32	931

From the above table we see that the maximum frequencies occurred between 2–3 A.M. and 0.1 P.M., whereas the minimum frequencies are between 6–7 P.M. and 0–1 A.M.

3. *Area Shaken in each Month in Square Ri.*

January	February	March	April	May	June	July	August	September	October	November	December	Total
18,230	14,820	21,520	18,060	13,010	10,700	11,830	14,410	9,250	19,240	9,310	14,320	174,700

4. *Area of Seismic Disturbances.*

The area shaken by the earthquakes varied with their intensity from a mere local tract up to several thousand square ri. 1 square ri=about 5·9 square miles. The following table is a classification of the earthquakes according to the area disturbed :—

Areas	January	February	March	April	May	June	July	August	September	October	November	December	Total	Average
More than 1,000 square ri .	5	5	7	6	3	4	1	3	3	5	3	1	46	3·8
From 1,000 down to 100 square ri	10	9	5	16	13	9	14	8	7	9	8	9	117	9·8
Less than 100 square ri . .	38	43	51	45	44	26	50	181	69	89	71	60	767	63·9
Total . . .	53	57	63	67	60	39	65	192	79	103	82	70	930	77·5

From the above table we see that 767 earthquakes out of the total number of 930 disturbed areas less than 100 square ri, 117 areas between 100 and 1,000 square ri, and 46 areas greater than 1,000 square ri. We may add that one earthquake shook an area of nearly 6,000 square ri, whilst another shook an area of about 9,000 square ri.

5. *Intensity of Earthquakes.*

During the year 1889, as we have seen, the total number of earthquakes was 930, of which 51 were of a severe character, 290 of moderate, and the remaining 589 were slight, shocks. Thus, severe ones were 6 per cent. of the total number of earthquakes, moderate ones 31 per cent., and slight ones 63 per cent.

Notes on Special Earthquakes.

1. February 18, at 6h. 9m. 0s. A.M., 6h. 27m. 0s. A.M., 7h. 48m. 52s. A.M., 8h. 2m. 0s. A.M., and 10h. 10m. 56s. A.M. The first shock was the strong one, shaking 5,750 square ri; 300 square ri near Tokio, where walls were cracked, tombstones overturned, clocks stopped, &c., was severely disturbed. The centre appears to have been in the Bay of Tokio. Earthquakes which are severe in Tokio seldom shake more than one or two neighbouring provinces, and, as measured by the land area which is shaken, they can only be considered as moderate disturbances. This earthquake, however, was felt on the West Coast, and shook 21 provinces (*see* ninth Report, 1889).

2. May 12, at 10.40 A.M. The shock disturbed 4,800 square ri in Central Japan. Thirty-seven provinces were shaken, Mino and Owari, the site of

the terrible catastrophe which occurred last year (1891), suffering the most.

In the neighbourhood of Gifu people were thrown into a state of alarm. The banks of the Nagara River were rent for some distance. There was much damage to porcelain, wine-bottles, &c. Pendulum-clocks, especially those facing towards the south or north, were stopped. According to the observations of the Gifu Observatory, the duration of the earthquake was about 2 minutes 30 seconds. The movement, which was very slight at first, was followed three minutes after by a violent shaking, and at the fifth second the range of motion to the north and south was 4 bu 4 rin (about $\frac{1}{2}$ in.). But, from the moment at which the east and west motion came into play, the intensity was so much increased that the two leaden cylinders of the seismometer, together with the index, were overthrown, which put an end to the observations. The maximum range, however, seems to have been about 21 mm.

3. July 28, at 11.40 P.M. A short description of this earthquake, by which 20 persons were killed, 74 wounded, and many buildings destroyed, is given in the tenth Report (1890). For a full account see the paper by Messrs. Sekiya and Kikuchi forming vol. xiii., Part II., of the 'Transactions of the Seismological Society,' also vol. xvi. of the same publication.

4. December 31, 1 P.M. This earthquake extended from Yezo in the north to beyond Tokio in the south, shaking 9,210 square ri of country. It seems to have originated in the bed of the Pacific.

Earthquakes Observed at the Central Observatory in Tokio.

Between January and December, in Tokio, 113 shocks were recorded, a list of which has appeared in previous Reports.

1. *Frequency of Earthquakes per Season.*

The following table will show the seismic frequency per month :—

January	February	March	April	May	June	July	August	September	October	November	December	Total
5	16	11	18	13	7	5	8	7	8	9	6	113

From the above table we see that the maximum frequency was in April, while the minimum one was in January and July.

The following table shows the seismic frequency per season :—

Spring	Summer	Autumn	Winter	Average
42	20	24	27	28

The following table shows the frequency in the hot and cold seasons :—

October to March. Cold	April to September. Hot	Average
55	58	56·5

2. *Daily Frequency of Earthquakes.*

The following table is a classification of earthquakes according to the time of occurrence :—

Months	Hours												Total
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	
FORENOON—													
January	—	—	—	—	—	—	—	1	—	—	—	—	1
February	—	—	—	—	—	1	2	2	2	—	1	1	9
March	—	1	—	—	—	-	2	1	1	—	1	—	6
April	1	1	1	1	—	1	—	1	—	—	—	—	6
May	—	—	—	—	—	2	1	—	1	2	1	—	7
June	—	—	—	—	—	—	—	1	—	—	1	—	2
July	—	—	1	—	—	—	—	—	—	—	—	—	1
August	—	—	—	—	—	—	—	1	—	—	1	—	2
September	—	1	2	—	—	—	1	1	—	—	1	—	6
October	—	—	1	—	1	—	2	—	—	—	—	1	5
November	1	—	2	—	—	—	—	—	1	—	—	—	4
December	—	—	—	—	—	1	—	—	—	—	—	1	2
Total	2	3	7	1	1	5	8	8	5	2	6	3	
AFTERNOON—													
January	—	—	1	1	—	—	—	1	1	—	—	—	4
February	—	—	2	1	—	1	—	—	—	2	—	1	7
March	—	—	1	—	1	1	1	1	—	—	—	—	5
April	1	—	2	2	4	1	—	—	—	1	1	—	12
May	2	1	—	—	—	—	1	—	—	—	1	1	6
June	1	1	1	—	—	—	1	—	—	1	—	—	5
July	—	—	—	—	—	1	1	—	1	—	1	—	4
August	1	1	1	2	—	1	—	—	—	—	—	—	6
September	—	—	—	—	—	—	—	1	—	—	—	—	1
October	—	—	—	—	—	—	—	1	—	—	1	1	3
November	1	3	—	—	—	—	—	—	1	—	—	—	5
December	1	1	—	—	—	—	—	—	1	—	1	—	4
Total	7	7	8	6	5	5	7	4	4	4	5	3	113

Thus we see that the maximum frequency occurred from 6 to 8 A.M. and from 2 to 3 P.M., whereas the minimum frequency occurred from 3 to 5 A.M.

3. *Intensity of Earthquakes.*

The remarkable earthquakes recorded in Tokio were those of February 18 and December 31, already referred to, which had durations of 8 minutes and 5 minutes 20 seconds respectively; and one on August 5, which had a duration of 4 minutes 20 seconds.

There was only one earthquake which had a maximum range greater than 20 mm. No other earthquake occurred with a maximum range greater than 10 mm. There were 12 earthquakes with a maximum range greater than 1 mm., and 25 earthquakes less than 1 mm. There were 75 earthquakes whose movement was so slight as to render it impossible to observe the range of oscillation. We therefore had very few severe disturbances during the year, although a large number of earthquakes were recorded.

4. *Direction of Earthquakes.*

The following table shows the number of earthquakes arranged according to direction :—

N. to S.	S.S.W. to N.N.E.	S.W. to N.E.	W.S.W. to E.N.E.	E. to W.	E.S.E. to W.N.W.	S.E. to N.W.	S.S.E. to N.N.W.	Uncertain
11	1	8	1	18	5	11	2	56

5. *Nature of Earthquakes.*

The following table shows the number of earthquakes according to the nature of movement :—

Nature	Months												Total
	January	February	March	April	May	June	July	August	September	October	November	December	
Both vertical and horizontal . .	2	1	4	6	2	1	1	2	1	2	—	2	24
Horizontal	1	9	2	2	3	4	2	3	—	1	4	—	31
Uncertain	2	6	5	10	8	2	2	3	6	5	5	4	58
Rapid	2	3	3	2	2	2	2	2	1	1	—	1	21
Slow	1	6	3	5	2	3	1	3	—	2	4	1	31
Uncertain	2	7	5	11	9	2	2	3	6	5	5	4	61

From the above we see that the number of earthquakes which were felt as a horizontal movement was greater than those in which horizontal and vertical motions were combined. There were 58 earthquakes the movement of which was indeterminate. As regards the velocity of back and forth motion, 31 out of 113 earthquakes were slow, 21 were rapid, and 61 were indeterminate.

Remarks on the above Reports.

The above notes are based on two epitomes of the work done in 1888 and 1889, by the Central Meteorological Bureau, which I have recently published in vol. xvi. of the 'Transactions of the Seismological Society.' The tables are altogether the work of the officers in the Meteorological Bureau.

Laws relating to the frequency of earthquakes which are sharply defined have not yet been discovered. During the winter months we know that earthquakes are more numerous than they are in summer, and if, instead of reckoning our earthquakes as efforts of equal value, we give to each a value corresponding to the area shaken, the fact that seismic energy is more intense during the winter than in summer becomes more pronounced. All areas given in this and previous Reports are *land* areas. A more satisfactory method of determining earthquake intensity would be to give total areas. In estimating frequency, it would seem that a series of secondary shocks, which may spread over a period of several months, but which are the outcome of a primary disturbance, ought either to be omitted, or at least to be regarded as belonging to the

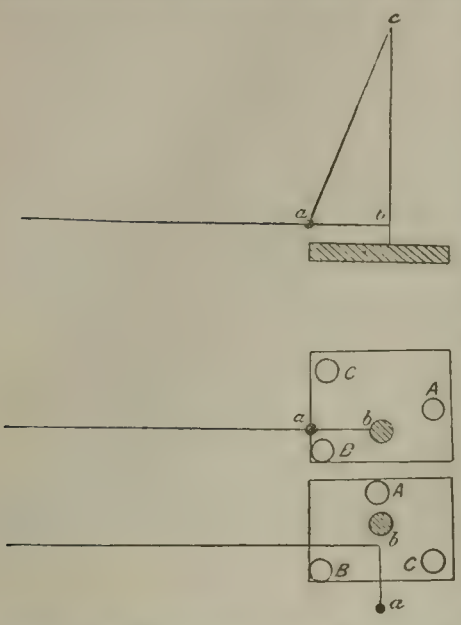
disturbance which gave them birth. If this is not done, then a large disturbance which took place, for example, near the end of the winter months may have the long series of shocks which follow, and which indicate that the conditions which lead to earthquakes are being destroyed, added in with the summer disturbances, and the rule that earthquakes are more frequent in winter is obliterated. An effect of this description is shown in the tables for 1889, which might have been drawn up omitting 281 secondary disturbances which occurred in Hiogo. In connection with these analyses it would seem desirable that earthquakes should be grouped according to their origins, and, in addition to what is done at present, separate analyses be made for each group. Some of the earthquakes which occur in the north of Japan do not appear to have any more connection with those which occur in the south of Japan than the earthquakes of Great Britain have with the earthquakes of Switzerland. The earthquakes from all these regions may conform with the law of winter frequency, but it is also desirable to know the relationship between earthquakes of a given group. Do the earthquakes which originate beneath the ocean follow the same laws as those which originate in our mountains? Is the occurrence of earthquakes at one particular origin more in accordance with some rule than the occurrence of similar disturbances at some other focus? With the aid of the four or five thousand maps showing the area shaken by every earthquake since 1885 such questions might be answered, but time and means for their analysis are thus far wanting.

On a New Method which may be Employed for Investigating Earth Tremors or Earth Tips.

In Reports to this Association in 1887 and 1888 I gave an epitome of the work which had been accomplished in investigating small earth movements called earth tremors. The more important results were, that tremors were most frequent with a low barometer, and they were especially noticeable if there was a steep barometric gradient. They often occurred when it was absolutely calm in Tokio, and often heralded the approach of a wind from the south-west. The instrument employed was automatic in its action, the records being made at intervals of five minutes. Being, like all other tromometers, of the ordinary pendulum type, it only indicated when tremors were strong and the time of their occurrence. The instruments which I have been using for the last few months give perfectly continuous records of earth tremors, measure them as to amount and direction, and throw considerable light upon the nature of these movements. From the character of the records it is also seen whether the column on which the instruments are placed remains horizontal or suffers tilting. Anyone possessing a small metal stand which has three levelling screws and a metal upright can, with a silk fibre, a small sewing-needle, a small shot, and a glass fibre, construct one of these instruments. In the sketch, *a b* represents the needle, with the shot fixed at *a*, and *a c* the fibre, which is secured at *a* and *c* by shellac. The glass fibre is joined to *b a* as a continuation of its length. This acts as a pointer, and moves above a mirror, on which there is a finely divided scale. The fibre may be replaced by a rigid wire, when it must be properly pivoted. Agate cups at *b* and *c* give greater sensibility. A complete

arrangement requires two such pieces of apparatus, which may be placed to work on the same scale as shown in the plan.

Everything must be well sheltered from currents of air. For a continuous record the glass pointer is replaced by a small galvanometer mirror, which reflects a ray of light through a slit into a box, where it is photographed upon a moving plate. The screws B and C serve to adjust the pointers and to measure the amount of tilting corresponding to any given displacement. By moving A the degree of stability is adjusted. I adjust *a b c*, which may be briefly described as an extremely light conical pendulum, until it has a period of about five seconds. With this adjustment the mirror or pointer may at any time be set swinging, and it will return to rest and show the reading from which it was displaced. Sources of error which may possibly interfere with the records which these instruments are supposed to give are as follow :—



1. By unequal expansion of different portions of one of these instruments the pointer or ray of light might be displaced. As at least four of these instruments, which are differently constructed, some with wire suspensions, and others with fibre suspensions, only vary in *amount* of displacement, and seldom, if ever, in *direction*, whilst the temperature is changing, it would seem that temperature effects are too small to be observed. Lighting a stove in the room and raising the temperature quickly does not appear to produce any effect. Good spirit-levels are subject to great changes by changes in temperature, and therefore it is difficult to use them as recorders of changes in level. I have had a pair of such levels under glass cases, standing on excellent stone columns, for several years, but the results were too unsatisfactory for publication. When they were side by side and parallel the bubble of one might move to the right, and the other to the left.

2. In consequence of hygroscopic changes the instruments carried by a silk fibre may possibly be affected. I have not observed such changes, but Mr. F. Ōmori, who is repeating my work, tells me that they are evident. I cannot imagine them to exist in the instruments which have wire suspension, and by the use of quartz fibres which Mr. F. Boys, F.R.S., has sent me, this possible source of error may be eliminated where fibres are employed.

3. Because the horizontal member of the conical pendulum has in several cases been a fine steel needle, magnetic effects may be introduced. If these are measurable, they must be extremely small. With a 3-foot ray of light during a tremor storm, the image may be continuously moving through a range of from 1 to 2 inches. This is too large to be magnetic. If a record for twenty-four hours is represented by a straight line 12 inches in length, I find that this from time to time is gradually

deflected from $\frac{1}{8}$ to $\frac{1}{4}$ inch from its true path, and the line, which is often straight, has one or two bow-like bends, suggesting that the column on which the instruments rest has been gradually lifted or warped for a period of, say, five or six hours, and then for the next four or five hours been gradually lowered or gradually returning to its original form. Occasionally this lifting process only takes from fifteen to thirty minutes. The character of the record is hardly that which would be expected as a result of magnetic influences.

Observations.

All my observations have hitherto been made upon a table-like stone column which forms the foundation of a column built some fifteen years ago to carry an equatorial telescope. It is 4 feet square, made of carefully squared blocks of stone measuring $4' \times 2' \times 1'\ 3''$, and rises $3'\ 6''$ above the floor of one of the rooms in my house which for many years was the Astronomical Observatory of the Imperial University. Unless the shutters of a window are closed for three or four hours the midday sun strikes the south face of the column. A fibre instrument photographically recording N. and S. motion stands near the N.E. corner of the column. On the N.W. corner a second fibre instrument shows E. and W. motion as a spot of light on a scale. Between these two a pair of wire instruments records N.S. and E.W. motions, and a second set of instruments records similar motions on the south side of the column. In between them, from time to time, similar instruments have been used in varying positions.

In regular use there were, therefore, three instruments recording N. and S. motion, and three which recorded E. and W. motion. Observations were commenced on December 18, 1891, and with but few interruptions they are being continued. A few of the more important results are as follows :—

Tremors.

1. On many occasions a stiff gale has been blowing, and although we should expect tremors if they were a direct effect of the wind, all the instruments have been still: as, for example, on January 15, with W. and S.W. wind; January 18, with N.W. wind; February 8, with S. wind; February 24, everything remarkably steady, with N.W. wind; February 27, strong N. wind and very slight tremors; March 1, N.W. wind; March 27, W. wind.

On each of the above days the wind was unusually strong. The revolving roof above the column and the shutters rattled, whilst each gust of wind caused my house, which is of wood, to shake. When this latter happened, by carefully watching the pointers of an instrument through a magnifying glass, they were seen to tremble, and each trembling, which was momentary, corresponded with the impulses of the wind upon the outside of the building. There was no swing produced in the pointers, but only a temporary vibration along their length. The movements consequent on 'earth tremors' are distinct and continuous angular displacements, and not the vibration of pointers.

2. Tremors often occur when the wind is high. They also occur when it is moderate, and when it is absolutely calm. The relationship of

such tremors to winds at a distance, and to barometrical gradients, have been discussed in previous Reports. Sometimes the tremors are only shown on the instruments recording N. and S. motion, sometimes only on those which record E. and W. motion, and sometimes they are marked on all the instruments.

3. One of the most important results obtained from the new method of observation is that the so-called earth tremors do not appear to be movements resulting from a general vibration in the soil, such as might, for example, be caused by the falling of heavy weights. With a tremometer of the ordinary pendulum type a simple swinging, corresponding to the period of the pendulum, is only seen; and although it has been observed that the swing is not always uniformly to the right and left of the same point, this swinging might still represent a cumulative effect of minute vibrations. With the conical pendulum arrangement, the inertia of which is extremely small, although they sometimes appear to be moving with their natural period, it is oftener that their vibrations appear to be forced. By watching the spot of light as it fitfully swings from side to side, sometimes quickly and sometimes slowly, during a tremor storm, it is difficult to avoid the conclusion that the movements are produced by the tilting of the column. For example, on the night of February 14, when the barometer was low (29·6) and but little wind, all the E. and W. instruments were moving, while the N. and S. were still. The E. and W. light from time to time swung between 32 and 39 (1 division =2·5 mm.), and it seemed as if at irregular intervals, which did not correspond with gusts of wind, that the east side of the column had been lifted. On February 16, in the afternoon, whilst a strong N.W. wind was blowing for some time, the E.W. spot of light rested at 30, then it would move to 34, but return to 30. Five minutes later it stood at 35, but now and then it would move quickly to 40, and return to 30. It did not swing evenly on either side of any point. Similar observations have been made on other days. With the N. and S. recorder these effects, which are apparently due to tilting, have only been observed once or twice, and they were not well pronounced. It is probable that these movements may be due to the same causes, which at the time of very heavy winds I have seen to cause the bubble of a delicate level to pulsate. One result of these observations is that, for the present, at least, I can no longer regard earth tremors as movements which correspond in character to vibrations like those which may be produced by a steam-hammer or a railway train—on which I have often experimented—but rather that they are wave-like pulsations, irregular in period, and producing changes in level.

They may possibly be the result of sudden variations in barometric pressure over large areas.

4. During a tremor storm, which sometimes lasts for twenty-four hours, the range of motion is very variable, the intervals between periods of maximum movement being sometimes ten or fifteen minutes. If these motions are due to tilting, this means that the slopes of the wave-like pulsations are not equally steep.

5. The photographic records, which refer to N. and S. motions—whether there are tremors or whether tremors do not exist—by the deviation of the spot of light, sometimes to the right or sometimes to the left, give evidence of angular motion of the mirror, which may be explained on the assumption of tilting of the ground, warping of the column

or portions of the instrument by change of temperature, a variation in the condition of the fibre by change in moisture, or as an effect due to magnetic influences. Sometimes it appears that the southern side of the column had risen or sunk within a period of fifteen minutes. At other times the movement takes several hours. Usually it takes about as long to sink as it did to rise; but this is by no means invariable, the upward motion being sometimes accomplished in a few minutes, whilst the lowering extends over several hours. The following are examples of these movements, which for *convenience* are described as an actual lifting or sinking of the south side of the column.

February 9.—During the day the south side rose slightly, and sank again towards night.

February 10.—About 4.30 A.M. the south sunk suddenly 2 mm., but in one hour returned to its normal position.

February 11.—Between the morning and the afternoon the south side rose slowly.

February 12.—No movement observable.

February 13.—Steady rise of the south side, commencing in the morning, and continuing until 8 P.M. and on to midnight.

February 14.—From midnight of the 13th the south sank, the greatest fall taking place during the afternoon. This sinking continued steadily to the 15th. On the 16th this sinking was irregular.

February 17.—Between 3.30 and 4.30 A.M. the spot of light moved 2 mm. to the right and back to the left, indicating a rising and then a sinking of the south side. A similar movement, but of from 4 to 5 mm., took place in fifteen minutes, commencing at 9.30 P.M.

February 18.—The south rose slightly during the day, and sank towards night. About midday there was a deflection like the two which took place on the 17th.

February 19.—During three hours the south sank, and then rose in three hours, the range of motion being about 6 mm. During the night the south again sank, and rose within a period of about three hours.

February 21.—Early in the morning the south slightly sank, and this continued until the afternoon, when within an interval of ten minutes it quickly rose. There was a sudden but slight sinkage at midnight.

February 24.—During the whole day, and also at night, the south was slightly sinking.

February 25.—During the day the south was rising.

February 26.—From 4 to 7 A.M. the south sank, after which it rose to 9 A.M. In the afternoon it again sank; &c.

The deflections referred to as measured on the photographic record are usually about 2 mm.; it is not unfrequent that they reach 5 or 6 mm., and once they were as much as 15 mm.

When the mirror has a period of four or five seconds, and it is 29 inches from the photographic plate, a deflection of 1 mm. might be due to a tilting represented by ·25 inch per mile. The sensitiveness of the apparatus may be changed by altering the period of the mirror. The approximation given may also be used in giving angular values for the tremors which have been observed.

The fact that the south side of the column appears to rise when the sun is on the south side of the house would indicate that the tilting was due to temperature, but as the same movements also take place during the night, and at irregular intervals, it cannot be an immediate effect of

sun-heat. Closing the shutters and blinds of the one window in the room does not alter the angular displacements. The N. and S. pointer of a glass fibre instrument standing on the S.E. corner of the column may be altered by lighting a small stove which stands within 3 feet of the column, and raising the temperature of the room 20° to 30° Fahr. In a few hours this corner of the column becomes quite warm to the hand, and the pointer shows that the southern side has been warped or tilted upwards. Although the fire may burn all day, I do not observe any change in the other instruments, and it is therefore difficult to imagine that the deflections which have been noted are the immediate result of a change in the temperature or hygrometric state of the atmosphere in the room where the column is situated. The character of the movements is hardly such as might be expected from changes in declination. At the Magnetical Observatory, about two miles distant from my house, whatever changes have been recorded do not coincide either in character or in time with the movements under discussion.

The conclusion arrived at is, that from time to time there is evidence that the column in my house is tilted sometimes quickly, but more generally slowly. The cause of this tilting is not inside the house, but outside. It may be local, and due to variation in the temperature or the moisture in the ground.

To determine whether the tilting extends over a considerable area a second photographic recorder is being erected in a seismological laboratory about 400 yards distant from my private observatory.

6. On January 28, at about 11.20 P.M., a small earthquake took place, after which it was observed that the N. S. pointers of all the instruments had been displaced in the same direction. It appeared as if the south side of the column had been slightly tilted. East and west pointers were not disturbed. Subsequent earthquakes in February did not produce any change.

Earthquakes are recorded as streaks of light across the plate, and as the instruments are so sensitive, they are capable of recording disturbances which ordinary instruments fail to indicate.

In making these investigations I am now receiving valuable assistance from Mr. F. Townley, in Yokohama, and Mr. James Murdoch, in Ōmori, each of whom is provided with tromometers. My colleague, Professor W. K. Burton, has given me most valuable assistance in carrying out the photographic part of my work.

Earth Tremors and Firedamp.

In 1884 I reported to this Association that in the previous year I had established a tromometer and other instruments underground in the Takashima Colliery, near Nagasaki. Shortly after they were put up a fall of the roof cut off access to the chamber where they were placed, and ever since they have remained buried beneath the bed of the Pacific Ocean. As Mr. John Stoddart, who took charge of the instrument, has died, and Nagasaki is so far distant, I have not been able to re-establish these observations, one of which was to determine whether the giving off of firedamp was in any way connected with earth tremors.

In the 'Proceedings of the Northern Institute of Mechanical and Mining Engineers,' Mr. Walton Brown draws attention to the possible

connection between earth shakes, tremors, and the issue of firedamp, and refers to the work attempted at Takashima.

Some years later the British Association appointed a committee to investigate their possible relationships, and I believe that seismographs and delicate seismoscopes were set up in the Newcastle district. At the time I pointed out that such instruments could only record earthquakes, and it was unreasonable to suppose that there could be any connection between earthquakes and the ordinary outpourings of firedamp. The instruments required were tromometers, rather than seismometers and seismoscopes, and in this Report I have defined the nature of the phenomena to be looked for, which are more like wave-pulsations than tremors. The instrument by which these may be investigated is the light form of conical pendulum already described. The records are not the same as those obtained from the *swinging* of a pendulum tromometer. We know that a curve showing the microseismic activity *in Italy* closely follows a curve showing the colliery explosions between 1860 and 1881 which have occurred in Germany. Unfortunately, we do not know anything about microseismic activity in Germany. From tromometric observations made at the École de Douai, by M. Chesneau, during February and March 1886, and from observations on the escape of gas estimated by a Pieler lamp at the Hérin Mine (Compagnie d'Anzin), we learn that certain relationships between these two phenomena were established (*see* 'De l'étude des mouvements de l'écorce terrestre poursuivie particulièrement au point de vue de leurs rapports avec les dégagements de produits gazeux,' par M. Raynal, Ministre des Travaux publics; M. B. de Chaucourtois, inspecteur général, assisté de MM. Ch. Lallemand et G. Chesneau, ingénieurs au Corps des Mines, 'Annales des Mines,' Mars-Avril, 1886).

Earth pulsations, like escapes of firedamp, usually take place when the barometer is low; but a more general rule for the occurrence of the former phenomena is, that they are observable whenever the district of observation is crossed by a steep barometric gradient. It would be of interest and of value to determine whether the escape of firedamp follows a similar rule, and, for the welfare of our mines and miners, tromometric observations ought to be inaugurated in the neighbourhood of some of the more fiery of our mines. The movements to be sought for are not minute earthquakes, tremors, or vibrations, but pulsatory movements which may be compared to the swell upon an ocean.

On the Overturning and Fracturing of Columns.

In the Report for 1891 a short account of the results of experiments on the overturning and fracturing of columns was given. Partly in consequence of the terrible disaster on October the 28th of that year, when thousands of structures of all descriptions were overturned, shattered, or utterly ruined, these experiments are being extended.

With regard to overturning we can now state with considerable accuracy the acceleration necessary to overturn a column-like structure of given dimensions. One set of experiments, in which Mr. F. Ōmori has continued to assist me, shows most clearly that a group of similar columns, whether they are large or small, heavy or light, so long as they have the same ratio of height to breadth, with horizontally applied motion will fall simultaneously. Further than this, the acceleration which was

recorded as having caused them to overturn is practically identical with that which may be calculated from their dimensions. The ratios of breadth to height varied from 1 : $2\frac{1}{2}$ up to 1 : 9, and in each group there were at least six columns. These ratios are identical with the dimensional ratios of gravestones and other bodies overturned by the last earthquake. The actual sizes of the columns experimented on were not small; for example, one column, where the ratio of breadth to height is 1 : $2\frac{1}{2}$, was $9\frac{1}{2}$ in. square and $25\frac{3}{4}$ in. high. One result of this work is that we can now go from place to place through the shaken district, and state with considerable accuracy the accelerations that were experienced. As we have one or two diagrams from the shaken area, we know, at least approximately, the period of the motion, and we can therefore calculate the amplitude and maximum velocity of motion which was experienced. Such calculations are now being made by Mr. F. Ōmori.

From the formula given in the last Report, which showed a relationship between the dimensions, weight, and strength of a structure, and the acceleration which would shatter the same, we are now able to calculate accelerations from shattering phenomena. The greatest difficulty which had to be overcome in making these investigations was the collecting and subsequently determining the strength of portions of masonry structures which had been ruined. Altogether, 26 cases of brickwork have been obtained from the earthquake district, and the testing of their contents has been completed. Reference is made to the results of the calculations based on these experiments under the section relating to the Great Earthquake.

The only new development of the fracturing formula has been to determine the form of a wall or pier which, rather than snapping at its base—as was the case with many structures at the time of the last earthquake, and also with all the columns subjected to back and forth motion on the earthquake track—would be as likely to break at any one horizontal section as at any other. The effect of the last earthquake was to cause brick piers of railway bridges to snap at their bases, and it would therefore seem that the basal section required greater strength. This might possibly be obtained by increasing the basal dimensions at the expense of a portion of the brickwork in their upper parts, which, so far as offering resistance to effects resulting from their own inertia, were apparently more than sufficiently strong. As a result both of reasoning and observation, it is evident that in earthquake countries, piers, walls, chimneys, and the like should have vertical sections different from those which they receive in ordinary practice. A full account of these experiments will be published in a 'Journal of Seismology' which is shortly to be issued.

The Great Earthquake of October 28, 1891.

If we may judge from the contortions produced along lines of railway, the fissuring of the ground, the destruction of hundreds of miles of huge embankments which guard the plains from river-floods, the utter ruin of structures of all descriptions, the sliding down of mountain sides and the toppling over of their peaks, the compression of valleys, and other bewildering phenomena, we may confidently say that last year, on the morning of October 28, Central Japan received as terrible a shaking as has ever been recorded in the history of seismology. It is a subject

that might be written about at interminable length, and therefore in this short Report no attempt is made to give detailed descriptions of all that happened.

Mr. F. Ōmori, who works with me in the Seismological Laboratory, has spent several weeks in the shaken district, and ever since has been busily engaged in analysing the materials he collected. Professor Tanakadate, with a staff of assistants, devoted himself to observations relating to the velocity of propagation of earth-waves, the curious sound phenomena, and, lastly, to a redetermination of magnetic elements in the devastated district. Dr. B. Koto has studied the phenomena from a geological standpoint.

Under the title of 'The Great Earthquake in Japan,' in conjunction with Professor W. K. Burton, I have published a general account of the more striking phenomena which were observed, illustrating the same by a series of photographs. The questions to which greatest attention has been given are those of importance to engineers and builders, but inquiries and investigations have been made relating to everything which was thought to be of interest. A few days after the disaster, at the request of Professor D. Kikuchi, I drew up a circular containing some fifty queries. Ten thousand of these documents were issued, and now, here and at the Central Observatory, we are surrounded by boxes filled with newspaper cuttings and replies. Five per cent. of the whole may be of value, but yet it has all to be patiently examined. In addition to this material, there is that of our own collecting, which, in addition to what has already been mentioned, includes some hundreds of diagrams taken by seismographs of what seemed to be at one time an unending series of shocks which followed the great disaster. This chaotic mass of material is gradually being sifted, and assuming a form suitable for systematic investigation. Although many of the results may be marked by the magnitude of the phenomena they represent rather than by their novelty, we have already gone sufficiently far to see that certain observations can hardly fail in widening the circle of our present knowledge.

The first notice that I received of the earthquake was at 6h. 39m. 11s. on the morning of October 28, whilst I was in bed. From the manner in which the house was creaking and the pictures swinging and flapping on the wall I knew the motion was large. My first thoughts were to see the seismographs at work; so I went to the earthquake-room, where to steady myself I leaned against the side of the stone table, and for about two minutes watched the movements of the instruments. It was clear that the heavy masses suspended as horizontal pendulums were not behaving as steady points, but that they were being tilted, first to the right, and then to the left. Horizontal displacements of the ground were not being recorded, but angles of tilting were being measured. That whenever vertical motion is recorded there must be tilting, and therefore no form of horizontal pendulum is likely to record horizontal motion, is a view I have often expressed. What I then saw convinced me that such views were correct. Next I ran to a water-tank which is 80 feet long, 28 feet wide, and 25 feet deep. Its sides are practically vertical. At the time it was holding about 17 feet of water, which was running across its breadth, rising first on one side and then on the other to a height of about 2 feet. It splashed to a height of 4 feet. It seemed clear that the tank was being tilted, first on one side, and then on the

other. Whilst this was going on trees were swinging about, telegraph-wires were clattering together, the brickwork of the tank was cracked, and the college workshop, a few yards away, was so far shattered that it has had to be partially rebuilt. The effect of the motion upon myself was to make me feel giddy and slightly sea-sick. The chimney of a paper-mill in Tokio fell, and also a chimney at the electric-light works in Yokohama.

The constructor of the latter chimney derived some satisfaction from the fact that it fell as a heap of loose brick round its base, for had it been made of better materials, it might have toppled over in large masses, and destroyed neighbouring buildings. Many structures were slightly fractured. During the day twenty-one other shocks were recorded, but nearly all of them were so slight that they failed to give a diagram sufficiently large for analysis. From the slow and easy, swinging nature of the motion, it was known that the shock was not of local origin, but that it had originated at a distance. As disturbances of this character had often reached us from an area beneath the Pacific Ocean about 400 miles to the north-east, it was from the northern parts that we expected to receive further information. The surmise that the origin was at a distance proved correct, but instead of being beneath the ocean to the north-east, it was beneath the land in an exactly contrary direction. The first news was that in Kobe, which is about 400 miles towards the south, many chimneys had fallen, earthquake shocks continued, and all were in alarm; whilst at Ōsaka, which is 356 miles from Tokio, a cotton-mill had collapsed and many people had lost their lives. Little by little news of destruction arrived from many towns, and as it came it grew more terrible. The scene of greatest disaster was the Nagoya-Gifu Plain, which lies about 140 miles W.S.W. of Tokio, and 80 miles N.E. of Kobo. In this district destruction had been total. Cities and villages had been shaken down, the ruins were burning, bridges had fallen, river embankments had been destroyed, the ground was fissured in all directions, and mountain sides had slipped down to dam the valleys. More accurate estimates of certain damages are now before us. The killed numbered 9,960, the wounded 19,994, and the houses which were *totally* destroyed were 128,750. In addition to these there were many temples, factories, and other buildings. In an area of 4,176 square miles, which embraces one of the most fertile plains of Japan, and where there is a population of perhaps 1,000 to the square mile, all the buildings which had not been reduced to a heap of rubbish had been badly shattered. To rebuild the railway, reconstruct bridges, roads, and embankments, and to relieve immediate distress, about one and three-quarter million pounds sterling have been poured into the district, the greater portion of which came from the Imperial treasury. This sum, however, only measures a fraction of the total destruction. One hundred thousand houses have yet to be rebuilt, irrigation works have to be repaired; a value has to be given to land which has been buried by landslides or lost by what appears to be a permanent compression of valleys; there has been a six-months interruption of traffic and of industries, and nearly 10,000 people have lost their lives—all of which are factors which cannot be overlooked when measuring the effect of an earthquake by the sum it takes to replace the damage it has occasioned.

The immediate cause of this great disturbance was apparently the formation of a fault which, according to Dr. B. Koto, can be traced on

the surface of the earth for a distance of between forty and fifty miles. In the Neo Valley, where it runs nearly N. and S., it looks like one side of a railway embankment about 20 or 30 feet in height. The fields at the bottom of this ridge were formerly level with the fields now at the top of it. In Mino, where it strikes towards the east, it is represented by subsidences and mound-like ridges, suggesting the idea that they might have been produced by the burrowing of a gigantic mole. Although there is only 20 feet of displacement on the surface, from what we know of surface disturbances resulting from the caving in of subterranean excavations, the maximum throw of this fault is in all probability very much greater than that which is accessible for measurement. Not only have the rice-fields been lowered, but, according to the peasants, the mountain peaks on the western side of the valley have decreased in height.

Not only is there evidence of subsidence along this line, but there are many evidences of horizontal displacements. Lines of roads have been broken, and one part of them thrown to the right or left of their original direction; whilst fields which were rectangular have been cut in two, and one-half relative to the other half been shifted as much as 18 feet up or down the valley. One result of this is that landowners find there has been a partial alteration in the position of their neighbours. A more serious change has been the permanent compression of ground, plots which were 48 feet in length now measuring only 30 feet in length. It appears as if the whole Neo Valley had become narrower. A similar effect is noticeable in the river-beds, where the piers of bridges are left closer together than they were at the time of their construction.

Since the big shock about 3,000 minor shakings have been recorded. At Gifu and Nagoya, where most of these were felt, their distribution with regard to time was as follows, the numbers representing the number of shocks which were recorded during successive intervals of ten days :—

Month	Day	Month	Day	Nagoya	Gifu
1891: X.	29	1891: XI.	7	559	1,132
XI.	8	XI.	17	123	341
XI.	18	XI.	27	76	116
XI.	28	XII.	7	48	139
XII.	8	XII.	17	40	190
XII.	18	XII.	27	27	75
XII.	28	1892: I.	6	36	87
1892: I.	7	I.	16	9	60
I.	17	I.	26	6	36
I.	27	II.	5	9	45
II.	6	II.	15	7	37
II.	16	II.	25	11	39
II.	26	III.	6	9	40
III.	7	III.	16	3	28
III.	17	III.	26	3	13
III.	27	IV.	5	9	42
IV.	6	IV.	15	1	26
IV.	16	IV.	25	4	28
		Total . .		980	2,474

The most violent shakings took place high up in the Neo Valley, on

the line of the great fault, and again in a district to the west of Nagoyal, about 25 miles farther south, in the middle of the Owari Plain. This second area of great disturbance may indicate the proximity of a second line of fracture not visible on the surface, or it may be an area where waves from various sides of the plane coalesced.

With the first of these shakings great landslips took place, and mountains which were green with forest now look as if they had been painted yellowish white. The valleys in these districts have been filled with débris, and behind one of the dams which has been formed there is now a lake six miles in circumference. In one district on the eastern side of the plain we are told that mountain peaks fell in and depressions were formed. Depressions also occurred in some of the valleys, and the houses of farmers suddenly sank up to their eaves, burying their inmates in a sea of earth and mud beneath the floor on which they once lived.

In the plains, river embankments which on the top are from 20 to 30 feet in width, and have slopes of 3 to 1 and 2 to 1, were very much cracked and fissured. Usually these cracks were 2 or 3 feet in width, but in places they had so far united that openings 10 or 15 feet wide and about the same in depth had been formed. In all cases the fissures were parallel to the river bank, and it was in villages near these banks where destruction had been most complete. It might be expected that these fissures would occur at distances of half wave-lengths from the river bank, and at similar distances from each other, but no such rule was observable. The general appearance of the ground was as if gigantic ploughs, each cutting a trench from 3 to 12 feet deep, had been dragged up and down the river banks.

Fissures, out of which sand and water had been poured, sometimes to form small craters, were also to be seen on the open plains. These fissures, which seldom exceeded a foot in width, and which may have been formed by the compression of watery strata beneath, may possibly give an approximate measure of maximum horizontal displacement, the direction of motion being at right angles to the direction of the fissure.

Along the railway-line many curious appearances were presented. It was almost everywhere more or less disturbed, the exceptions being where it passed through small cuttings. Along these cuttings, although they might not be more than 20 or 50 feet in depth, the rails and sleepers were unmoved; from which it may be inferred that the movement on the free surface of the plain had been much greater than the movement at a comparatively shallow depth. Measurements of the motion experienced on the surface and that recorded in pits 10 to 20 feet in depth have already been given in former reports. The results of these experiments have been practically applied to several buildings in Tokio, by giving them basements and a free area. The Imperial College of Engineering is such a building. It does not show the slightest trace of damage after the last earthquake, whilst at a distance of 20 yards the workshop, which is also a strong brick building, but rising from the surface, as already stated, has had to be rebuilt. This is the third time the Engineering College has escaped damage, whilst neighbouring brick buildings have been cracked in almost every room.

Where the line was on the open plain, and only separated from it by a narrow ditch on either side, it appeared as if the ground had moved back and forth beneath the track until the gravel ballast had been piled up into bolster-like ridges between the sleepers. This indicated a longitudinal

motion, but in many places it was noticeable that the sleepers, relatively to the ground, had been moved endways. Neither of these movements greatly exceeded 6 inches. Wherever the line crossed a small depression in the general level of the plain, even if it did not exceed 2 or 3 feet, at such places the whole of the track was bent from its straight course into a bow-like form, suggesting the idea that along these depressions, which are probably filled with softer material than that composing the plain, a greater quantity of motion had been transmitted, which, striking the line like a flood, had caused a permanent deflection. The more reasonable explanation is that these lines of soft material, like the valleys and river-beds, had been permanently compressed, and the amount of compression was measured by the amount of bending. Effects of compression were most marked on some of the embankments, which gradually raise the line to the level of the bridges. On some of these the track was bent in and out until it resembled a serpent wriggling up a slope. Not only were there these horizontal foldings, but by subsidence or compression there were vertical folds, which in places gave the line the appearance of a switchback. Close to the bridges the embankments had generally disappeared, and the rails and sleepers were hanging in the air like huge catenaries.

At the bridges, one of which, over the Kisogawa, and made up of 200-feet spans, is 1,800 feet in length, the destruction was various. In nearly all cases wing walls had given way. At one brick bridge the abutments had been forced backwards, and the arch had fallen bodily between them down upon the roadway, where it lay in two big segments, looking like a gigantic toggle-joint. At the Nagara Bridge the piers, each of which consisted of five large iron columns filled with concrete and braced together, had in several instances not simply been broken at their bases, but they were snapped in pieces and thrown out upon the shingle beach of the river, where they lay like bits of broken carrot. The bridge was thrown 19 feet out of a straight line, and one of the foundations near the centre of the river moved 5 feet 2 inches up-stream. Where the greatest deflections occurred the foundations could not be positively recognised.

Mr. C. A. W. Pownall, who constructed these bridges, and who gave me the above measurements, estimates the deflection on the line where it approaches the bridges at 1 foot 6 inches in a distance of 90 feet. The distance through which the foundations of the Kiso Bridge have permanently approached each other is 2 feet in a span of 200 feet—that is to say, the contraction across the river-bed is 1 per cent. When all the piers of a bridge had not been broken, it was observed that those which escaped were the shorter ones, near the river banks. The longer piers of the Kisogawa Bridge had a cross-section of 22·5 feet by 10 feet, and a height of 29 feet above the plane of fracture, which was 4 or 5 feet above their foundations. They carried girders weighing about 200 tons. The shorter piers, which also had a cross-section of 22·5 feet by 10 feet, had heights of about 21 feet above their planes of fracture. They carried girders weighing about 22 tons.

The tensile strength of the brick and cement work of these piers was, as shown by actual tests, unusually high, often reaching 100 lb. to the square inch. When making these tests, it was seldom that the cement gave way, fracture taking place either by the breaking of the brick or by *separation* between the cement and brick.

The tensile strength of brick and mortar work from cotton-factories and other private buildings seldom exceeded 5 lb. to the square inch.

Professor Tanabe, of the Imperial College of Engineering, has very kindly applied the fracturing formula to the Kisogawa and other structures, with the following results:—

The tall piers at the Kisogawa Bridge, which were broken, were capable of resisting an acceleration of 5·05 feet per sec. per sec., whilst the shorter piers, which were also broken, could have resisted a force involving an acceleration of 10·8 per sec. per sec.

The acceleration in the neighbourhood of this bridge was therefore greater than the higher of these two numbers; because there is no necessity that one set of piers out of a series should only have half the strength of another group in the same series, or that any given structure should be weaker at its base than it is in its upper parts. So far as resistance to stresses consequent on horizontal movement is concerned, the writer ventures to express the opinion that when constructing in an earthquake country, ordinary engineering practice requires modification. Such modifications are being made by Mr. C. A. W. Pownall in the construction of a series of bridges now being built up the Usui Pass, in this country.

For the Nagara Bridge, where cast-iron piers have snapped in two, the accelerations experienced have not yet been calculated.

Leaving the railway works, and examining the various brick-and-mortar structures, like public buildings and mills, which existed at many towns upon the plain, we meet with hardly anything but absolute ruin. Two conspicuous brick-and-mortar ruins in Nagoya were the Post Office and a cotton-mill. Walls like these, even if not weakened by openings near their base, assuming them to have been 40 feet high and $1\frac{1}{2}$ foot thick, and with a tensile strength for their brickwork of 5 lb. per square inch—which is not an underestimate—might have resisted a suddenness of motion of a few inches per sec. per sec. From overturning phenomena and diagrams we know the acceleration impressed upon buildings in this area may have been as much as 15 feet per sec. per sec.

One curious form of destruction was that which was observed with many mill chimneys, which, with the exception of one in Yokohama, instead of breaking at their bases, gave way at about two-thirds their height. Sections near the bases of these chimneys were apparently sufficiently strong to resist the stresses due to the inertia of the upper parts, while sections at about two-thirds the height were so weak that they failed to resist the inertia effect of the upper one-third of the chimney. Calculations respecting these structures have not yet been made.

The ruins of ordinary Japanese buildings existed along all the roads in never-ending lines. In some streets it appeared as if the houses had been pushed down from the end, and they had fallen like a row of cards. Where a row of buildings had only been partially pushed over, it was noticeable that those at the end had suffered more than their neighbours. Sometimes you passed acres of heaped-up rubbish, where sticks and earth and tile were so thoroughly mixed that traces of streets or indications of buildings had been entirely lost.

Many of the ruined towns, like Kasamatsu and Gifu, caught fire, and all that remained was a sea of reddish earth and broken tile. At several places people were caught in the fallen ruins, and subsequently burnt to

death. The chief causes which led to the destruction of Japanese buildings were :—

1. The heavy roofs, which are usually made of a heavy framework carrying a layer of heavy tiles bedded in a thick layer of mud. The roofs of the farmers' houses are covered with a heavy thatch. These latter fell intact, and even now the country is covered with these saddle-shaped masses, which have served as temporary tent-like shelters.

2. The want of cross-bracing and the thinness of the vertical supports, the strength of which is reduced to perhaps an eighth of what it might be by a variety of tenons, mortices, and other cuts, made for the reception of cross-timbers.

Both of these faults in the construction of an ordinary Japanese dwelling might be easily overcome, but from the buildings which are now being erected it is clear that the survivors prefer that to which they have been accustomed and can easily obtain. Buildings to resist earthquake motion are outside the experience of ordinary carpenters in Japan, and any novelty in construction would be expensive. For these reasons, coupled perhaps with the idea that severe earthquakes only recur at long intervals, the inhabitants of the Nagoya district are giving another trial to the old forms of construction.

Among the buildings which were only shattered, but which did not fall, are two castles and several heavy-roofed temples.

The castles stood, partly, perhaps, because they were well built, partly because they were surrounded by deep moats, but chiefly on account of their pyramidal form, their bases being sufficiently wide and strong to withstand effects due to the inertia of their upper parts.

The temples undoubtedly resisted the severe movements partly because they were well built, but chiefly, perhaps, on account of the multiplicity of jointed corbel-work, which comes between the upper parts of the supporting pillars and the heavy roof. If this had not existed, and acted as a yielding medium between the roof and its supports, it seems impossible that the latter could have resisted the inertia of the load above them.

A class of buildings which here and there escaped entire destruction were structures like some of the school-houses, which were built of wood, and framed according to foreign methods.

The movements which caused all this terrible destruction throughout the Gifu and Nagoya Plain do not appear to have been waves which were entirely those of elastic compression and distortion. On the coast-line to the north of the devastated district we are told that the shore-line rose and fell, and with this rising and falling the waters receded and advanced. In the district itself many eyewitnesses tell us that they saw the ground in waves.

Mr. Kildoyle, an engineer, who at the time of the disaster was in Akasaka, says that the waves came down the street in lines. Their height may have been 1 foot, and the distance from crest to crest anything between 10 and 30 feet; but he very naturally added that he could not be sure of any measurements, as he was expecting that the houses on one side or the other of the street might at any moment fall in upon him. It may here be remarked that because on the street side of the houses in a town there are many openings, which make this side of the buildings weaker than they are at the back, the tendency is to fall forwards from two sides into the street. For the safety of the inhabitants

of a town, special attention ought to be given to the construction of shop and other frontages, and the streets be made wide.

Another indication of wave movement is the statement of people who say that after they had been thrown upon the ground the movements of the earth rolled them from side to side. A station-master, who tumbled on the line as the station-house fell close behind him, showed the writer the manner in which he seized one of the rails whilst lying on the ground, the rail passing between his legs. While in this position he was tumbled from side to side, first striking the ground with one shoulder, and then with the other.

Reasons for believing that in Tokio the ground was thrown into long undulations have already been given. First, there was the evidence of our sensations; secondly, the observation of the manner in which water moved in ponds; and, thirdly, the observations on the movements of bracket seismographs, which were tipped from side to side. The most certain evidence about the tilting is, however, that which is furnished by the diagrams of many seismographs, which, rather than showing a series of irregular waves with superimposed irregularities, in almost all cases show a series of clean-cut curves. In one instrument which was tested the periodicity of these curves did not agree with the period of the instrument, from which we may conclude that they had not been formed by swinging. Further, the periods of a consecutive series of waves are not constant. For example, one set of east and west tiltings followed each other, with periods measured in seconds of 3·4, 2·0, 2·7, 1·7, 4·1, 3·1, 3·1, 2·7. On another instrument another set of waves, taken at random, followed each other at intervals of 1·9, 2·5, 1·3, and 2·6 seconds. These observations also preclude the idea that the records were obtained by swinging. The most interesting observation, however, is that a pair of conical pendulums, the bobs of which were supposed to be steady points, and which had no pointers for multiplication, gave diagrams about twice as large as similar, but smaller, conical pendulums which carried pointers to multiply any motion relative to their bobs six times.

The actual records are as follows :—

—	N.S. Motion	E.W. Motion
	in.	in.
Large pendulums with booms 18 inches long . . .	8	13
Small pendulums with booms and *pointers* 9·5 inches long	4	8

On the assumption that the bobs of these machines had acted as steady points, we should come to the conclusion that the range of north and south motion had been 8 inches, as given by one instrument, whilst it was only ·66 inch as given by another, both instruments being in the same building. It is clear that these two instruments had not behaved as modern seismographs are supposed to behave at the time of an earthquake, but because the displacements indicated are practically proportional to the length of boom, or the length of boom and pointers, that the instruments had been tilted, and the extent of the displacement measures maximum slopes of earth-waves. To interpret these measurements, it is necessary to place a level on the stand of the seismograph, and determine by experiment the angular values of tilting corresponding to measured

movements of the writing-pointers, the latter quantities varying with the amount of stability given to the horizontal pendulums. Immediately after the earthquake Mr. F. Ōmori very kindly made such determinations for a seismograph in the laboratory of the Imperial University, with the result that the maximum slopes which this seismograph had recorded were about one-third of a degree. Waves with these slopes, as shown on the diagram, succeeded each other at intervals of about 2·2 seconds. The vertical motion which was recorded was about 10 mm.; but as ordinary lever spring instruments, when the levers are not parallel to the wave-fronts, are as sensitive to tilting as horizontal bracket or conical pendulum seismographs, these measurements must be regarded as maximum rather than actual values. Combining the maximum wave-slopes with these records of vertical motion, we obtain certain values for the lengths of the waves, which may be taken at 18 or 20 feet; and as we know their period, we may determine their velocity of propagation, which appears to have been about 8 feet per second. This is exceedingly slow, but notwithstanding the errors in the observation of vertical motion, I do not think the velocity exceeded double this amount. The velocity of propagation of more truly elastic vibrations will be referred to later.

From these observations, which I think are made for the first time, rather than concluding that modern seismographs are useless whenever vertical motion occurs, we see that on such occasions they must be regarded as angle-measurers. The action of any bracket seismograph when recording horizontal motions depends greatly upon its inertia, but to obtain the best measurements of tilting, any cause likely to produce swinging should be minimised. To obtain a true measurement of vertical motion, the method which first suggests itself is to have a number of spring lever arrangements in different azimuths, the one which happened to have its arm at right angles to the direction in which the wave advanced being the one which would give the best results.

Independently of any new instruments which may be devised to measure tilting, we now know that the instruments we already possess have a double function, not only measuring horizontal displacements, but also measuring angles of tilting. In order to take advantage of this second function, it is necessary that when a bracket or conical pendulum instrument is once set up, experiments should be made to determine the effects of tilting, otherwise, should it be tilted by an earthquake, its records will not be measurable.

An investigation of considerable importance in connection with the intensity and direction of motion, which has been carried out by Mr. F. Ōmori, relates to the overturning of bodies of various dimensions. At all temples, which are more thickly distributed than the towns and hamlets, there are stone lanterns, standing on circular or square pedestals, whilst in the vicinity there are hundreds of gravestones, which are square or rectangular in section, and stand freely on their ends. Applying the overturning formula to some thousands of these which were overturned in the Nagoya-Gifu Plain, average minima and maxima values for the accelerations experienced at different points within the earthquake area have been determined. Inasmuch as the results given by the formula, which is due to Professor C. D. West, conform with the results obtained by experiment, we have every confidence in the figures given in the following table:—

Average Intensity and Mean Direction of Shock as experienced at Various Places in the Shaken Area. Calculated by Mr. F. Ōmori.

Place, District, and Province	Intensity in Millimetres per sec. per sec.	Direction
Tsu, Ano, Tse	<2,000	S. 70° E.–N. 70° W.
Yokkaichi, Miye, Tse	<1,900	S.E. by E.N.W. by W.
Kuwana, Kuwana, Tse	2,000	E. 10° N.–W. 10° S.
Tokonabe, Chita, Owari	<2,400	E.–W.
Handa, „ „	2,000–2,700	S.E.–N.W.
Toyohashi, Atsumi, Mikawa	1,700–1,800	S. 75° E.–N. 75° W.
Okazaki, Nukada, „	<900	
Atsuta, Aichi, Owari	2,300–3,500	E.N.E.–W.S.W.
Northern part of Nagoya (Toshogō)	2,600	S. 80° W.–N. 80° E.
North-eastern corner of Nagoya (Kenchiuji)	2,600	S. 60° W.–N. 60° E.
Central part of Nagoya	2,500	
Mean for Nagoya	2,600	S. 65° W.–N. 65° E.
Bamba, Kaito, Owari	>4,100	E.N.E.–W.S.W.
Tsushima, „ „		E.–W.
Jimmokuji „ „		E.–W.
Shimo-Osai, Nishi Kasugai, Owari		Nearly N. and S.
Komaki, Higashi-Kasugai, „	>4,000	Chiefly E. and W. say W.S.W.–E.N.E.
Twakura, Niwa, „	>4,300	Chiefly N. and S. say S.S.W.–N.N.E.
Koori, „ „	>2,100	S.W.–N.E.
Tmaichiba „ „	>2 ,60	
Tnagi „ „	2,300–4,000	S. 15° W.–N. 15° E.
Tchinomiya, Nakajima „	2,500–3,500	W.N.W.–E.S.E.
Kasamatsu, Haguri, Mino	4,000	W.N.W.–E.S.E.
Gifu, Atsumi „	3,000	W.S.W.–E.N.E.
Ogaki, Ampachi, „	3,000	N.N.E.–S.S.W.
Kitagata, Motosu „		Nearly E.–W.
Beppu, „ „	>3,900	
Kurono, Katagata, „		S. 50° W.–N. 50° E.
Monju, Motosu, „		S. 60° W.–N. 60° E.
Kojibara, „ „	<1,900	N. 20° W.
Komi, „ „	>2,000	S. 60° W.
Higashi-Katabira Kani, Mino	>2,400	N.–S.
Dota, „ „	<2,200	S. 20° W.–N. 20° E.
Tmawatari, „ „		N.–S.
Mitake, „ „	About 1,600	W.N.W.
Takayama, Toki, „	>1,800	
Tokiguchi, „ „	>2,000	N. and S.
Tajimi, „ „		S.S.W.–N.N.E.
Tkeda-Machiya, „ „		S. 20° W.–N. 20° E.
Utsutsu, Higashi-Kasugai, Mino	2,000	S. 35° W.–N. 35° E.
Akechi „ „	>2,000	
Ono, Ōno, Echizen	>1,200	E.–W.
Katsuyama, „ „	About 1,200	Nearly N.–S.
Fujishima, Yoshida, „	>1,300	„ N.–S.
Fukui, Asuwa „	2,500	N.N.E.–S.S.W.
Asozu, „ „	<1,100	S. 30° W.
Midochi, Tmadate „	About 2,000	
Sabai, „ „	„ 1,800	
Takefu, „ „	„ 1,200	N.–S.
Higashiura, Tsuruga, „	„ 1,300	
Tsuruga, „ „	„ 1,200	N.N.W.–S.S.E.
Nagahama, Sakata, Ōmi	„ 2,400	Nearly N.–S.
Hikone, Onukami, „	„ 2,700	N.N.W.–S.S.E.

AVERAGE INTENSITY AND MEAN DIRECTION OF SHOCK, &c.—*continued.*

Place, District, and Province.	Intensity in Millimetres per sec. per sec.	Direction
Kioto, Yamashiro . . .	< 1,200	S.S.W.–N.N.E.
Tnari, Kii, „	About 1,000	N. 10° W.–S. 10° E.
Fukakusa, „ „	> 1,000	N.–S.
Fushimi, „ „		S.S.E.–N.N.W.
Nara, Yamato		S.S.W.–N.N.E.
Horiuji „	About 1,300	S.S.E.–N.N.W.
Osaka, Suttsu	„ 1,000	

The principal measurements obtainable from the records of seismographs are as follows :—

1. *Tokio. Central Meteorological Station.*

Maximum horizontal motion, N. and S., about 28 mm. Period, 1·4 sec.
„ „ „ E. and W. > 32 mm. „ 2·5–4.0 secs.
„ vertical „ 3·1 mm., with period ·84 sec., and 4·4 mm. with period 2·3 secs.

2. *Tokio. Imperial University.*

Maximum horizontal motion, > 35 mm. Period, 2·0 secs.
„ vertical „ 9·5 mm. „ 2·4 secs.

3. *Osaka.*

Maximum horizontal motion, 30 mm. Period, 1·0 sec.
„ vertical „ 8 mm. „ 1·0 sec.

4. *Nagoya.*

Maximum horizontal motion, > 26 mm. Period, 1·3 sec.
„ vertical „ 6·2 mm. „ 1·5 sec.

5. *Gifu.*

Maximum horizontal motion, 18 mm. Period, 2·0 secs.
„ vertical „ > 11·3 mm. „ 0·9 sec.

At the two latter places the records only showed the first half-dozen vibrations of the disturbance, after which the buildings fell, and the instruments were buried.

At several places in the Neo Valley objects like gateposts have apparently shifted their positions by jumping, each leap being from 1 to 4 feet.

Another observation, also due to Mr. Ōmori, is that the greater number of columns in one district fell in one direction, whilst those in another district fell in some other direction. Thus, in the southern part of the Nagoya-Gifu Plain, on its eastern side, columns fell towards the coast, whilst at towns on the western side of the plain they fell towards the east—an observation which suggests that the movements causing overturning had advanced eastwards and westwards, from a line or tract running north and south down the centre of the plain. In the northern

part of the plain the direction of motion, similarly determined, must have been more north and south.

From the measurements of maximum acceleration, and from the records of seismographs which at Nagoya and Gifu gave for the commencement of the disturbance the period of the back and forth motions, we may approximately determine the amplitude and maximum range of motion. The following are a few of such determinations, which it will be observed do not materially differ from the width of fissures found in the open country. The period taken is one and a half second:—

Place	Acceleration mm. per sec.	Range of Motion
West of Nagoya . .	4,500	495 mm. = $19\frac{1}{2}$ inches
Komaki and Kasamatsu .	4,000	440 mm. = $17\frac{1}{2}$,,
Gifu and Ogaki . .	3,000	330 mm. = 13 ,,

It must be remembered that all the numbers given referring to acceleration and range of motion only apply to the open plain, and not to free surfaces like river banks or lines of soft material like river-beds. A phenomenon which seemed to accompany most, if not all, of the Nagoya-Gifu shocks was a hollow, booming sound. These sounds, which accompany all great earthquakes, and even small ones, if they occur in rocky regions, have been discussed at considerable length in the 'Transactions of the Seismological Society' (*see* vol. xii. p. 53, and p. 115). They are evidently the result of vibrations conveyed through the earth, and may be continuous with the large vibrations which constitute the earthquake. Professor Tanakadate endeavoured to determine the intervals in time between the sounds and the subsequent shakings. Sometimes there was an interval of one or two seconds, whilst at other times the two phenomena were synchronous. The distance of the point of observation from the origin of these disturbances was in all probability at least 10 or 12 miles. While the writer was at Nagoya, which may have been from 25 to 35 miles distant from the earthquake origins, the sounds never preceded a shaking by more than two seconds. Sometimes they were synchronous, and often there were sounds without any subsequent shaking.

Very many observations were made in Tokio, on the Gifu Plain, and in other places, to determine the velocity of propagation. These have not yet been computed, but disturbances appear to have reached Tokio at rates of about 8,000 feet per second.

From observations made at the Zikawei Observatory, near Shanghai, which is, roughly, 1,000 miles distant, the velocity with which the movement was transmitted was about 5,104 feet per second. As stated in newspapers, the time taken to reach the Berlin Astronomical Observatory, in round numbers, was forty-nine minutes, the velocity of transmission being about 9,840 feet per second. The disturbance appears also to have been noted at the Magnetical Observatory in Potsdam.

Although numerous experiments and observations have been made to determine the velocity with which motion is conveyed through the earth, we have not as yet any satisfactory explanation of the great differences which have been observed.

From a long series of experiments, extending over several years, which were made in Tokio, where earth disturbances were caused by

exploding charges of dynamite, velocities were obtained varying from 200 to 630 feet per second. All these experiments were made in alluvium. Amongst other results the following were of importance:—

1. The velocity of transit decreases as a disturbance radiates.

2. The velocity of transit varies with the intensity of the initial disturbance.

3. The motions transmitted most rapidly are vertical free-surface vibrations; normal motions come next, whilst the lowest records obtained were for transverse motions (*see* 'Trans. Seis. Soc.,' vol. viii. p. 50, &c.).

Mr. Mallet determined a velocity in sand of 824·915 feet, and in granite, of 1664·576 feet per second. General Abbott, at the destruction of Flood Rock, noted velocities as high as 20,526 feet per second. Professor S. Newcomb and Captain C. Dutton determined velocities for the Charleston earthquake of 17,072 feet per second. The highest velocity for a sound-wave through piano steel of density 7·7 is given by Tomlinson at 5,198 metres (17,049 feet) per second.

Although elastic vibrations may have been transmitted from the earthquake district 150 miles to the Tokio Plain at the rate of several thousand feet per second, the resultant gravity-waves in the Tokio Plain itself do not seem to have been propagated at a greater rate than a few feet per second. With these results before us, all we can say is, that earthquakes have caused motions in the ground, which apparently have been transmitted at rates varying between 10 feet per second and 20,000 feet per second, the latter being a rate which is higher than that at which sound-waves are propagated through hard steel. Attention has often been called to these facts, but any explanation for them has not yet been formulated.

The result of Professor Tanakadate's magnetic survey has not yet been published, but I believe he finds that there is a slight irregularity in the curve, showing the daily change in declination, which does not appear to have been noticed before the earthquake. A curious observation, made by Dr. Julius Scriba and other medical men, was that many of the troubles amongst the wounded, like tetanus and erysipelas, were in great measure due to the result of nervous excitement. From my own observations at a time when all were camped in the midst of ruin, and every few minutes a shock was heralded by a booming sound, the only effect that the great catastrophe had produced upon the people was, when they heard one of these unaccountable noises, to cause them to act with unusual quickness in seeking safety. Amongst the Japanese, so far as I could learn, there was no hysteria, fainting, or nervous prostration like that which was observed amongst European women. Although they were surrounded by ruin, the dead, and the dying, all that happened when a hollow thundering announced a coming shock was that they ran quickly for the open, shortly afterwards coming back laughing and talking about the terrible effects of earthquakes. Notwithstanding this, it is not unlikely that this disaster will have produced an impression sufficiently great that for many a year to come it will be commemorated by a religious ceremony, when services will be performed in honour of the dead.

The Nagoya-Gifu Plain is a flat expanse of rich alluvium, covering an area of about 600 square miles. On its east and west sides it is fringed by low hills made out of tertiary tuffs lying at the feet, palæozoic mountains which rise to heights of from 2,000 to 4,000 feet. These latter,

which stand up in serrated ridges and overlook the plain, are composed of slates, schists, and other metamorphic rocks. Here and there beds of limestone are found, and rising from the midst of these hills are several larger granite bosses. Volcanic rocks do not exist in this part of Japan. From ancient maps and historical accounts we know that the southern portion of this plain has rapidly been encroaching on the sea. This is, no doubt, largely due to sedimentation; but because evidences of elevation exist at so many places along the eastern coast of Japan, it is reasonable to infer that the growth of land may in part be attributable to this cause. A certain number of earthquakes are every year recorded in the Nagoya-Gifu Plain, but it is by no means so often shaken as many other parts of the Empire. A somewhat remarkable observation connected with the seismological history of this portion of Japan is the fact that, although written records of natural phenomena are usually fewer the further we go back in time, yet, from what has been chronicled, great earthquakes were more frequent in the district between Nagoya and Osaka in bygone times than they have been during more recent times. The last severe shakings at and near Gifu took place in 1826, 1827, and in 1859. Many ordinary buildings and even mountains suffered, people and animals were killed, rivers were stopped up, and floods occasioned. The shocks lasted for several days. A rather severe shock was felt on May 12, 1889. In 1880 there were shocks and sounds coming from the north-west. From 1885 to 1890 the number of shocks annually recorded in that district was respectively 9, 4, 10, 12, 15, and 36. In 1888, in one locality near to the centre of the late disturbance, 19 shocks were recorded; in 1889 the number was 15; in 1890 there were 20 shocks; and between January and October 1891, that is, up to the time of the great disturbance, 26 shocks were noted. These figures suggest the idea that for four years before the Great Earthquake there was a marked increase in seismic activity, and that an unusual number of small disturbances had heralded the great collapse.

Even if it is only sometimes true that small shakings warn us of larger ones to follow, because the latter are so terrible in their effects, it would seem well to carefully study districts in which from time to time there are definite indications of an increase in underground activity.

Earthquakes generally occur in mountainous countries where the mountains are geologically young, or in countries where there is evidence of slow secular movements like elevation. These latter movements are usually well marked in volcanic countries, and it is not unlikely that the majority of earthquakes, even in volcanic countries, are the result of the sudden yielding of rocky masses which have been bent until they have reached a limit of elasticity. The after-shocks are suggestive of the settling of disjointed strata.

In Japan, the majority of the earthquakes which we experience do not come from the volcanoes, nor do they seem to have any direct connection with them. Assuming that the greater number of earthquakes represent interruptions in the general process of rock crumpling, it would appear that light might be thrown upon the time of their occurrence by careful observations on the change of level in a district where seismic disturbances were frequent. To accomplish this it is suggested that several miles of water-pipes be laid at right angles to a known axis of elevation, and that continuous photographic records be kept showing the height of the water in standards at each end of the line. A more com-

plete arrangement would be to have two lines of piping, placed at right angles. The cost of the installation would be about 500*l*.

In conclusion to this Report it must not be overlooked that the remarks on the Great Earthquake only aim at giving an outline of phenomena which have been observed, and the general character of the results to which they lead. More detailed accounts will not be ready for publication for some months.

Nineteenth Report of the Committee, consisting of Professor EVERETT, Professor LORD KELVIN, Mr. G. J. SYMONS, Sir A. GEIKIE, Mr. J. GLAISHER, Mr. W. PENGELLY, Professor EDWARD HULL, Professor PRESTWICH, Dr. C. LE NEVE FOSTER, Professor A. S. HERSCHEL, Professor G. A. LEBOUR, Mr. A. B. WYNNE, Mr. W. GALLOWAY, Mr. G. F. DEACON, Mr. E. WETHERED, *and* Mr. A. STRAHAN, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water.* (*Drawn up by* Professor EVERETT, *Secretary.*)

REGRET has been expressed in previous Reports at the scarcity of observations from America. An important contribution towards supplying this lack is described in the 'American Journal of Science and Art' for March, 1892, under the heading 'Preliminary Report of Observations at the Deep Well, Wheeling, West Virginia, by William Hallock.' A copy of this Preliminary Report was sent by Mr. Hallock to the Secretary, and further details have been elicited by correspondence. The passages between inverted commas in the following account are in Mr. Hallock's own words.

The well belongs to the Wheeling Development Company. 'It was commenced in September, 1890, and sunk with rapidity to about 4,100 ft. by April, 1891. Then the Company, despairing of getting oil or gas, were about to abandon it, when Professor I. C. White persuaded them to deepen it and give it to science. Drilling was recommenced, and early in May they stopped at a depth of 4,500 ft., fearing to go further with the old Manilla rope.'

'The hole was sunk by the ordinary oil-well outfit, *i.e.*, a jumper drill on a rope.' It is dry, with the exception of a few feet of water at the bottom.

'About ten days after drilling stopped, Mr. F. H. Newell' and Mr. Hallock 'took a series of temperatures at every 250 ft.'

'The thermometers, immersed in zinc buckets of water, 3 ft. high and 4 inches in diameter' ($\frac{7}{8}$ inch less than the diameter of the bore), 'were left in place for twenty-four hours. This series of May does not differ essentially from the later ones of June and July, and shows no sign of heat due to jumper.'

'In June' Mr. Hallock 'returned to Wheeling, and during June and July made two very careful and complete series, which are given in the table. Each series touched every 250 ft.; but the two series were shifted

so that the points of one series fell midway between those of the other series, thus touching every 125 ft. or thereabouts. When it is considered that these two series were taken a month apart, and yet nowhere differ by more than 0°·3 F., it seems pretty good evidence of the accuracy and constancy of the results. Many of the points, as at 1,590, 2,500, 3,000, 3,500, 4,000, and 4,460, were checked as many as four or five times.'

The thermometers were raised and lowered by steel wire, which also served to measure the depths. They were lowered to place about 11 A.M., and left till next morning, though trials showed that they had practically reached a stationary condition by 5 or 6 P.M. Sometimes they were left in for several days. They were of the Negretti maximum kind, used upside down. They were carefully compared, and corrections were applied not only for their index errors, but also 'for the contraction of the recording column in cooling from the maximum temperature to the temperature at which they were read. They were put two (sometimes three) together, and hence always checked each other, agreeing very satisfactorily. They were hung upon a long spiral spring in the zinc bucket in water, or upon the wire 250 ft. from the bucket at the end.'

The well is cased with iron tubes to the depth of 1,750 ft. There are three of these tubes, the first reaching from the top to the depth of 400 ft., the second from the top to 1,200 ft., and the third or innermost from the top to 1,570 ft., the internal diameter of this last being $4\frac{7}{8}$ inches. No reliance was placed on the temperature of the cased portion.

The strata are nearly horizontal, their dip being only 50 ft. to the mile; and the uncased portion consists almost entirely of shale, the only important exception being an oil sand at from 2,900 to 3,000 ft. The conditions are eminently favourable for the purposes of the Committee.

In view of the disturbance of temperature by convective circulation of water, which was proved to exist in the deep bores at Sperenberg and Schladebach (see Reports for 1876 and 1889), and was obviated by the use of special plugs for isolating any required portion, Mr. Hallock made careful experiments on the effect of isolation. Two series of woollen wads were placed ten feet apart, and thermometers in the intervening space gave the same indications as other thermometers above and below the wads. 'In fact a thermometer simply tied on to the steel wire recorded the same as an isolated one.' Nevertheless, as a measure of precaution to prevent circulation, long blocks nearly filling the hole were nearly always placed above and below the thermometers, except when they were in the long buckets.

In endeavouring to account for the absence of convection in this dry bore, we are confronted with the fact that air is much more expansible than water, and therefore more easily put in motion by difference of temperature. On the other hand, the process of 'jumping' which was employed in the present case leaves the sides much rougher than diamond boring, which was the method employed at Sperenberg and Schladebach; and this roughness tends to hinder circulation.

The main difference to which we must look for the explanation is the difference of thermal capacity; this capacity, for equal volumes, being about 3,000 times as great for water as for air. It would thus appear that the air is so easily warmed and cooled, that the heat which it gives and takes does not sensibly affect the temperature of the walls, surrounded as they are by a practically infinite extent of rock tending to maintain them at their original temperatures.

The following is the Table of Observations:

Depth, Feet	Temperature, Fahr.	Depth, Feet	Temperature, Fahr.
	°		°
1,350	68·75	3,125	88·40
1,591	70·15	3,232	89·75
1,592	70·25	3,375	92·10
1,745	71·70	3,482	93·60
1,835	72·80	3,625	96·10
2,125	76·25	3,730	97·55
2,236	77·40	3,875	100·05
2,375	79·20	3,980	101·75
2,486	80·50	4,125	104·10
2,625	82·20	4,200	105·55
2,740	83·65	4,375	108·40
2,875	85·45	4,462	110·15
2,990	86·60		

When these observations are plotted they give a remarkably smooth curve. The portion from 1,835 to 3,232 ft. is nearly straight, with an average gradient of 1° F. for 82·4 ft. It then becomes gradually steeper.

Beginning at the point where the casing stops, viz., 1,591 ft., the first 244 ft. (1,591 to 1,835) give an average gradient of 1° in 92 ft.

The next 651 ft. (1,835 to 2,486) give 1° in 84·5 ft.
The next 746 ft. (2,486 to 3,232) give 1° in 80·6 ft.
The next 643 ft. (3,232 to 3,875) give 1° in 62·4 ft.
The next 587 ft. (3,875 to 4,462) give 1° in 58·1 ft.

The mean gradient for these 2,871 ft. (1,591 to 4,462) is 1° in 71·8 ft.

To determine the surface temperature, advantage was taken of a heading at the depth of 100 ft., which was being driven into new ground in a neighbouring coal-mine. A thermometer inserted in a hole bored 3 ft. into the face of the heading showed 51°·3 on five successive days. This is checked by the mean annual temperature of the two neighbouring towns, Marietta and Steubenville, which, according to the Coast Survey, is 51°·5. Comparing the temperature 51°·3 at 100 ft. with 110°·15 at 4,462 ft., we have a mean gradient of 1° F. in 74·1 ft.

The public spirit shown by the Wheeling Development Company in deepening this bore at great expense for purely scientific purposes cannot be too highly commended. There is reason to hope that the boring will be continued, with the aid of a steel rope, to at least 6,000 ft., so as to make this the deepest well in the world.

Mr. Hallock, by whom the plan of observation was devised and carried out, is senior assistant in the Astrophysical Observatory of the Smithsonian Institution, Washington.

[A request for information as to the temperature of the water at the bottom has been answered by Mr. Hallock since the reading of the Report. The temperature of the water was observed in May 1891, and found to be 110°·36 at the depth 4,492 ft., as the mean of three observations, viz., 110°·4, 110°·5, 110°·2, at the respective depths 4,500, 4,500, and 4,475 ft.

Mr. Hallock adds that this water leaked in at the depth of about 2,900 or 3,000 ft. and ran down, amounting to about ten or fifteen gallons per day.]

Report of the Committee, consisting of Professor G. CAREY FOSTER, Lord KELVIN, Professor AYRTON, Professor J. PERRY, Professor W. G. ADAMS, Lord RAYLEIGH, Dr. O. J. LODGE, Dr. JOHN HOPKINSON, Dr. A. MUIRHEAD, Mr. W. H. PREECE, Mr. HERBERT TAYLOR, Professor EVERETT, Professor SCHUSTER, Dr. J. A. FLEMING, Professor G. F. FITZGERALD, Mr. R. T. GLAZEBROOK (*Secretary*), Professor CHRYSTAL, Professor J. J. THOMSON, Mr. W. N. SHAW, Mr. J. T. BOTTOMLEY, Mr. T. GRAY, Professor J. V. JONES, Dr. G. JOHNSTONE STONEY, *and* Professor S. P. THOMPSON, *appointed for the purpose of constructing and issuing Practical Standards for use in Electrical Measurements.*

THE work of testing resistance coils at the Cavendish Laboratory has been continued. A table of values found for the coils is appended. The Committee have ceased issuing standards in terms of the legal ohm of the Paris Congress. As will be seen from Table I., most of the coils tested are ohms as defined by the resolutions of the Committee and the Electrical Standards Committee of the Board of Trade (*see* 'B.A. Reports,' 1890 and 1891). According to these

1 B.A. unit= ·9866 ohm.
1 ohm =1·01358 B.A.U.

TABLE I.

B.A. Units.

No. of Coil		Resistance in B.A. Units	Temperature
Warden Box 79	No. 1*a*	·99929	17°·7
	No. 1*b*	·99973	17°·7
	No. 1*c*	·99954	17°·7
	No. 10*a*	9·9928	17°·8
	No. 10*b*	9·9947	17°·8
	No. 10*c*	9·9941	17°·8
Elliott, 230	No. 80	1·00016	14°·4

Ohms.

No. of Coil		Resistance in Ohms	Temperature
Elliott, 259	No. 206	·99744	15°·5
Elliott, 260	No. 207	9·9788	15°·6
Nalder, 3059	No. 326	·99941	14°·5
Elliott, 271	No. 327	·99805	15°·4
Elliott, 272	No. 328	·99810	15°·8
Elliott, 273	No. 329	·99795	15°·4
Elliott, 276	No. 330	·99811	15°·5

TABLE I.

OHMS—*continued.*

No. of Coil		Resistance in Ohms	Temperature
Elliott, 274	No. 331	9·9860	17°
Elliott, 275	No. 332	9·9862	17°·1
Elliott, 277	No. 333	9·9862	17°·1
Nalder, 3260	No. 334	·99912	14°·7
Nalder, 3261	No. 335	9·9970	14°·5
Nalder, 3058	No. 336	·99897	13°·9
Nalder, 3265	No. 337	·99668	13°·9
Elliott, 284	No. 338	·99870	12°·7
Elliott, 285	No. 339	·99856	12°·9
Elliott, 286	No. 340	·99670	12°·8
Elliott, 287	No. 341	9·9707	12°·8
Nalder, 3259	No. 342	·99879	13°·2
Nalder, 3262	No. 343	9·9955	13°
Edison Swan	No. 344	9·9945	14°·5
Nalder, 3402	No. 345	·99971	16°·7
Nalder, 3403	No. 346	·99967	16°·5
Nalder, 3404	No. 347	·99970	16°·7
Nalder, 3405	No. 348	·99960	16°·4
Nalder, 3406	No. 349	·99960	16°·3
Nalder, 3564	No. 350	·99962	16°·4
Nalder, 3565	No. 351	·99957	16°·4
Nalder, 3566	No. 352	·99960	16°·5
Nalder, 3567	No. 353	·99949	16°·4
Nalder, 3568	No. 354	·99961	16°·5
Nalder, 3569	No. 355	·99964	16°·5
Nalder, 3558	No. 356	9·9928	15°
Nalder, 3557	No. 357	99·902	14°
Nalder, 3558	No. 358	999·09	13°·8
Edison Swan	No. 359	·99994	14°·4

Of the ohm coils the three first in the table have been tested before ('Report,' 1891). It was thought desirable to reissue the certificates in terms of the new ohm standards. A large number of the other coils

were constructed as legal ohms, hence the values of the resistance given in ohms at temperatures of 14° or 15° are low. The coils in many cases are very nearly legal ohms at the temperatures given, while they will be ohms some 8° or 10° higher.

In addition to the coils given in the table, four ohm coils constructed by Messrs. Elliott Bros. for the Board of Trade, one of which is to be selected as the legal unit of resistance for the United Kingdom, were tested very carefully. Some fourteen or fifteen comparisons were made for each coil at temperatures between 9° and 18° between June 1891 and January 1892. The coils were compared directly with the B.A. unit 'Flat,' the difference being expressed in terms of the bridge wire; while in another series of observations a coil of resistance, 100 ohms, was put in multiple arc with the ohm standard and the difference between 'Flat' and the combination found; in this case the length of the bridge wire used was small, and the possible error arising from uncertainty as to its exact temperature was avoided. That this error was very small was proved by the fact that the two sets of observations gave practically identical results. The following are the results :—

Elliott, 261 . . .	No. 300	1+	·000309 ($t-15{\cdot}35$)
Elliott, 262 . . .	No. 301	1+	·000310 ($t-15{\cdot}35$)
Elliott, 263 . . .	No. 302	1+	·000300 ($t-15{\cdot}4$)
Elliott, 264 . . .	No. 303	1+	·00031 ($t-15{\cdot}4$)

In the case of two of the coils, Nos. 261 and 263, there was one observation for each which differed from the value given by the above formula by ·00015 ohm, and this was due to the fact that the ends of the coils had got dirty and needed reamalgamation. None of the other errors in the sixty observations exceeded ·00008 ohm, and there were only eight which were as great as ·00005. Thus the resistances of these coils are known in terms of the B.A. standards to a very high degree of accuracy.

During the year Messrs. Elliott Bros. have supplied the Committee with two 1-ohm and two 10-ohm standards; the tests of these are in progress; two 100-ohm standards are on order. Messrs. Nalder Bros. are also constructing some standards. The Fleming bridge belonging to the Association has been put into thorough repair; the mercury had damaged some of the copper connecting pieces.

The Secretary and Mr. Skinner have continued during the year their experiments with Clark cells. These have been communicated to the Royal Society, and the paper is being printed in the 'Phil. Trans.'

They find that the E.M.F. of their standard cell is 1·4342 volt at 15° C., while cells set up by Lord Rayleigh in 1883, 1884, Mr. Elder in 1886, Mr. Callendar in 1886, Dr. Muirhead in 1890, Dr. Kahle of Berlin, Dr. Schuster, Mr. Wilberforce, Mr. Griffiths, and themselves in 1891 and 1892 agree closely, the variations among them all being very rarely greater than ·0005 volt.

During the Edinburgh meeting the Committee were honoured with the presence of Dr. von Helmholtz, M. Guillaume of Paris, Professor Carhart of the United States, Dr. Lindeck and Dr. Kahle of the Berlin Reichsanstalt. These gentlemen came by invitation to consider the question of establishing identical electric standards in various

countries, and two meetings of the Committee were held, at which discussions took place. Major Cardew, of the Board of Trade, was present, and took part in the discussion. Dr. von Helmholtz drew special attention to the need for having a unit of resistance defined in terms of a specified column of mercury, and pointed out that the difficulty arising from the uncertainty of the relation between the centimetre and the gramme might be avoided by defining the mass of mercury column of given length, which has a resistance of one ohm. After discussion the following resolutions were agreed to:—

1. That the resistance of a specified column of mercury be adopted as the practical unit of resistance.

2. That 14·4521 grammes of mercury in the form of a column of uniform cross section 106·3 m. in length at 0° C. be the specified column.

3. That standards in mercury or solid metal having the same resistance as this column be made and deposited as standards of resistance for industrial purposes.

4. That such standards be periodically compared with each other, and also that their values be redetermined at intervals in terms of a freshly set up mercury column.

It was further agreed that these resolutions should be communicated to the Electrical Standards Committee of the Board of Trade.

With regard to the unit of current and of electromotive force, it was agreed that the number ·001118 should be adopted as the number of grammes of silver deposited per second from a neutral solution of nitrate of silver by a current of 1 ampère, and the value 1·434 as the electromotive force in volts of a Clark cell at 15° C.

Dr. von Helmholtz expressed his full concurrence in these decisions, which are, as he informed the Committee, in accord with the recommendations which have already been laid by the Curatorium of the Reichsanstalt, as well as by himself, before the German Government.

The Committee wish to place on record their thanks to Dr. von Helmholtz and the other visitors for the help they have afforded them in coming to so satisfactory a conclusion.

Dr. Lindeck laid before the Committee some information as to the properties of the manganese alloy used at the Reichsanstalt for resistance coils (*see* Appendix IV.), and it was agreed that it was desirable to obtain copies of the German standards in manganese for further comparison with the standards of the Association. The Committee therefore recommend that they be reappointed, with the addition of the name of Mr. George Forbes, and with a grant of 25*l.*, including an unexpended balance of 10*l.*; that Professor G. Carey Foster be Chairman, and Mr. R. T. Glazebrook, Secretary.

APPENDIX I.

Information circulated by the Secretary for the Meeting of the Committee on August 4, 1892, *with additional Notes.*

The Report of the Electrical Standards Committee of the Board of Trade is printed in the 'B.A. Report' for 1891. Further information as to the values of the units is given in the 'B.A. Report' for 1890. The following summary may be of use:—

Table II.

I. *The Value of the Ohm.*

—	Observer	Date	Method	Value of B.A.U. in Ohms	Value of 100 Centimetres of Mercury in B.A.U.	Value of Ohm in Centimetres of Mercury
1	Lord Rayleigh	1882	Rotating coil	·98651	(·95412)	106·31
2	Lord Rayleigh	1883	Lorenz method	·98677	—	106·27
3	Mascart	1884	Induced current	·98611	·95374	106·33
4	Rowland	1887	Mean of several methods	·98644	·95349	106·32
5	Kohlrausch	1887	Damping of magnets	·98660	·95338	106·32
6	Glazebrook	1882 and 1888	Induced currents	·98665	·95352	106·29
7	Wuilleumeier	1890	—	·98686	·95355	106·31
8	Duncan and Wilkes	1890	Lorenz	·98634	·95341	106·34
9	Jones	1891	Lorenz	—	—	106·31
			Mean	·98653		106·31
10	Strecker	1885	An absolute determination of resistance was not made. The value ·98656 has been used.	—	·95334	106·32
11	Hutchinson	1888		—	·95352	106·30
12	Salvioni	1890		—	·95332	106·33
12*	Salvioni —	—		—	·95354	106·30
			Mean	. . .	·95354	106·31
13	H. F. Weber	1884	Induced current	Absolute measurements compared with German-silver wire coils issued by Siemens or Strecker.		105·37
14	H. F. Weber	—	Rotating coil			106·16
15	Roiti	1884	Mean effect of induced current			105·89
16	Himstedt	1885	—			105·98
17	Dorn	1889	Damping of a magnet			106·24
18	Wild	1883	Damping of a magnet			106·03
19	Lorenz	1885	Lorenz method			105·93

The Board of Trade Committee recommended for adoption the values ·9866 and 106·3.

The specific resistance of mercury in ohms is thus

$$\cdot 9407 \times 10^{-4}.$$

Also 1 Siemens unit = ·9407 Ohm
= ·9535 B.A.U.
1 Ohm =1·01358 B.A.U.

The results found by Lord Rayleigh were reduced by the use of the value for the specific resistance of mercury in B.A. units found by him. If instead we use the value ·9535, the mean of the best determinations, we have, as in the table, for the length of the mercury column having a resistance of 1 ohm the values 106·27 and 106·31. At the meeting of the Committee M. Guillaume stated that a correction should be made to M. Wuilleumeier's value, which would raise it to 106·31. This arose from some uncertainty as to the correction required to the resistance of mercury for change of temperature on which M. Guillaume had been working lately. Taking these corrections we arrive at 106·31 as the mean of the above.

2. *The Electrolysis of Silver.*

The following values have been found for the mass of silver deposited from a solution of silver nitrate in one second by a current of 1 ampère :—

Mascart, 'J. de Physique,' iii. 1884	·0011156
Rayleigh, 'Phil. Trans.,' ii. 1884	·0011179
Kohlrausch, 'Wied. Ann.,' xxvii. 1886 . . .	·0011183
T. Gray, 'Phil. Mag.,' xxii. 1886 . . about	·001118
Potier et Pellat, 'J. de Physique,' ix. 1890 . .	·0011192

Dr. Schuster has shown ('Proc. R.S.,' l. 1892) that the amount of silver deposited when the voltameter is in a vacuum is about ·04 per cent. greater than when it is in air.

3. *Clark Cells.*

The following values have been found for the E.M.F. of a Clark cell at 15° C. They have been reduced from those given in the original papers on the supposition that 1 B.A.U. =·9866 ohm, and that the mass of silver deposited per second per ampère is ·001118 gramme :—

Rayleigh, 'Phil. Trans.,' ii. 1884	1·4345 Volt
Carhart	1·4340 „
Kahle, 'Zeitschrift für Instrumentenkunde,' 1892 .	1·4341 „
Glazebrook and Skinner, 'Proc. R.S.,' li. 1892 .	1·4342 „

A comparison has been made between the standards of the Association and the Berlin standards through a Clark cell and a resistance coil belonging to Dr. Schuster. By the kindness of Dr. von Helmholtz the Secretary is able to communicate the results of a direct comparison between the two sets of standards to the meeting (*see* Appendix VIII.).

APPENDIX II.

On the Change of Resistance of Mercury with Temperature.
By M. G. Guillaume.

At the meeting of the Committee M. Guillaume communicated the results of his determination of the relation between the resistance of mercury and the temperature. Great precautions were taken with the view of ensuring that the whole of the mercury in the tube should be at the temperature of the bath.

Two series of determinations with different arrangements in the bridge were made. The results of these two series give for the resistance of mercury in a glass tube in terms of the temperature the values—

$$(a)\ R_t = R_0\,(1 + \cdot00088023T + \cdot0000010063T^2);$$
$$(b)\ R_t = R_0\,(1 + \cdot00088157T + \cdot0000009909T^2).$$

And for the specific resistance of mercury the values—

$$(a)\ \rho_t = \rho_0\,(1 + \cdot00088745T + \cdot0000010181T^2);$$
$$(b)\ \rho_t = \rho_0\,(1 + \cdot00088876T + \cdot0000010022T^2).$$

In the formulæ T is the temperature reckoned from freezing-point by the air thermometer. According to Mascart, de Nerville, and Benoit—

$$R_t = R_0\,(1 + \cdot0008649T + \cdot00000112T^2);$$

while according to Strecker—

$$R_t = R_0\,(1 + \cdot000900T + \cdot00000045T^2).$$

APPENDIX III.

On a Special Form of Clark Cell. *By* Professor H. J. Carhart.

Portability.—Standard cells must be portable in order to make them serviceable for general, technical, and scientific purposes. To secure portability I have adopted the following construction: Into the bottom of a glass tube $\frac{3}{4}$ in. $\times 2\frac{1}{4}$ in. is sealed a platinum wire. In filling pure distilled mercury is first poured into the tube. On this is placed the mercurous sulphate paste. A tightly fitting cork diaphragm is then pushed down firmly upon the paste. Some zinc sulphate solution is then poured in, and a zinc rod is immersed in this solution, its lower end touching the cork. The tube is then securely sealed. Such a cell is perfectly portable, and may be sent by post without disturbance to its contents.

Temperature Coefficient.—It is well known that an increase in the density of the zinc sulphate solution decreases the E.M.F. of a Clark cell. This effect is included in the temperature coefficient of a Clark cell containing crystals of zinc sulphate, since some of the crystals dissolve when the temperature rises and the density increases. When the temperature falls recrystallisation occurs. To avoid the change in E.M.F. due to this change in density I have preferred to use a solution saturated at 0° C. Such a solution I have found to have a specific

gravity of 1·397 at 20° C. The E.M.F. of the cell is then 1·44 volt if the Clark cell as made by Lord Rayleigh be taken as 1·434 volt.

The temperature coefficient may be written as follows :—

$$E_t = E_{15}\{1 - \cdot 000386\,(t-15) + \cdot 0000005\,(t-15)^2\},$$

or per degree the coefficient is

$$-\cdot 000387 + \cdot 000001\,(t-15).$$

This is almost exactly half the value usually obtained for the Clark cell with crystals.

A cell made with such a solution has the advantage that it reaches its equilibrium quickly after a change of temperature. Cells made in the old way require time for the process of crystallisation and for diffusion.

APPENDIX IV.

On Wire Standards of Electrical Resistance. By Dr. St. Lindeck, *Assistent bei der Physikalisch-Technischen Reichsanstalt, Charlottenburg, Berlin.*

It is well known that electrical resistances made out of the alloys generally used for this purpose, as German-silver, nickelin, &c., change their value in the course of time, and this in a degree which cannot be allowed in measurements meant to be at all accurate. Such a variation is naturally the greater the more unstable the material and the shorter the time elapsed since winding.

The following is a short account of the researches conducted in the Physikalisch-Technische Reichsanstalt in Charlottenburg on this subject by Dr. Feussner and myself. That investigation had to be undertaken specially, as it is one of the duties of the Electrotechnical Laboratory of this institution to secure that reliable standards of resistance may be obtainable by electricians.

We found by preliminary experiments that by more or less continued heating a coiled wire showed an interesting variation of its resistance, which led to a systematic investigation of the whole question.[1]

For different materials we determined:—

1. The chemical composition, the temperature-coefficient, and the specific resistance of the material.
2. The variation of resistance through the strain produced by winding.
3. The time-variation during the period subsequent to winding.
4. The influence of heating to different temperatures.

A piece of the double silk-covered wire was wound on a wooden bobbin and its ends soldered to thick copper bars. The bobbin was placed directly in a petroleum bath, in order to determine exactly the temperature, and its resistance was accurately measured by a Wheat-

[1] Some of the results here quoted as to the influence of stress and of a moderate rise of temperature were previously arrived at by Dr. T. Klemenčič (*Sitz.-Ber. Wien. Akad.* 97, 1888).

stone's bridge arrangement. As regards the variation of resistance through winding, it was observed that the resistance of all kinds of wire increased by winding, as would be expected, the increase being more pronounced for a given gauge of wire the less the bobbin's diameter. This increase is due to a mechanical hardening of the wire by strain, and it is well known that the resistance of any metal is less in the annealed state than in the hardened condition. At the same time an elongation can hardly be avoided, especially with thin wires, also causing an increase of resistance. As the gauge of the wires generally was 1 mm., this second cause was of secondary importance.

In the first place we investigated a German-silver alloy which the firm of Siemens & Halske in Berlin used for standards at that time. It appeared that the increase of resistance through winding could amount to 1 per cent., and that the time-variation during the following months was very considerable; the latter showed itself always as an *increase* of resistance. Another remarkable circumstance is the further *increase* of resistance (amounting to a few tenths per cent.) by heating such a wire for several hours at about 100° C.

It might be supposed that the wire would be annealed by the effect of the high temperature, and that its resistance would therefore decrease. But our extensive investigations gave the important result that heating causes an *increase* of resistance in all alloys containing zinc to any considerable amount. On the other hand, all alloys examined containing no zinc show a *decrease* of resistance under the same conditions. The increase of resistance by winding is also much more pronounced with alloys containing zinc than with those in which this metal does not occur. All this seems to point out that in the former alloys changes of structure go on, which are accelerated by any kind of stress or by variations of temperature, and always tend to increase the resistance. These changes of structure also become apparent by the time-variations, which occur when the resistance coil is left to itself. The latter observations are in perfect agreement with what was found by former observers on the time-variation of German-silver. The interesting result was then arrived at, that the time-variation would be much accelerated by heating the resistance at a high temperature, say 100° C., for a few hours. Within two months after winding, the period in which German-silver varies most, variations could not be shown within the errors of observation in wires treated in the manner described. During longer periods, say one or two years, variations would still occur, even with annealed German-silver coils. But they hardly reach the tenth part of those occurring when this process has not been gone through.

The following table shows the results of one of the experiments with two wires of German-silver (60 per cent. Cu; 25·4 per cent. Zn; 14·6 per cent. Ni), the specific resistance of this material being 30 microhms per $\frac{cm}{cm^2}$, and its temperature-coefficient 0·036 per cent. per degree Centigrade. In both cases the wire (1 mm. in thickness) was wound on a bobbin of 10 mm. diameter. The wire marked I. was left to itself after winding, whereas the wire II. was annealed after winding by heating it to a temperature of 90° Centigrade during three hours. The resistance of each was measured at intervals of nearly two months from time to time.

TABLE III.—*German-silver.*

I. (not annealed after winding)			II. (annealed after winding)		
Date	Resistance at 20° C. (in Ohms)	Remarks	Date	Resistance at 20° C. (in Ohms)	Remarks
1889			1889		
13/II.	2·2460	Before winding	13/II.	2·2470	Before winding
14/II.	2·2594	After winding. *Increase* through winding, 0·60 per cent.	14/II.	2·2666	After winding. *Increase* through winding, 0·87 per cent.
15/II.	2·2597	—	15/II.	2·2733	After heating to 90° C. during three hours; *increase* through heating, 0·29 per cent.
16/II.	598	—	16/II.	732	—
22/II.	603	—	22/II.	733	—
4/III.	608	—	4/III.	734	—
19/III.	612	—	19/III.	729	Temperature changed during the measurement
6/IV.	615	Time-variation in two months, 0·09 per cent.	6/IV.	732	Time-variation in two months, practically nothing

The above table shows clearly that annealing a wire after winding has a very good effect on the constancy of the resistance.

Quite analogous results were obtained with other alloys containing zinc, *e.g.*, nickelin, which has been much used for standards in Germany. The less the percentage of zinc, the less became the above-mentioned variations of resistance.

As these zinc-containing alloys showed themselves so unreliable, we extended our investigations to other alloys.

A few years ago the firm of Siemens & Halske in Berlin made use of an alloy on account of its comparatively low temperature-coefficient (0·02 per cent. per 1° C.), called patent-nickel. This was tested in the Reichsanstalt in the same way as the other alloys. It contains about 25 per cent. of nickel and 75 per cent. of copper. The experiments gave the following results :—

1. The variations of resistance by winding are considerably less for this material than with alloys containing an appreciable amount of zinc.

2. Heating produces a *decrease* of resistance ; this decrease is sometimes greater than the increase by winding, because the hardening produced by drawing the wire is also diminished. There is, however, not the slightest evidence for a change of molecular structure.

Materials with such properties are evidently much more appropriate for the construction of standard resistances. It was, indeed, found, by comparison with mercury resistances, that coils of 'patent-nickel,' which had been, as we call it, artificially aged by heating at about 140° C., have remained constant for two years within a few thousandths per cent. In the following table, for instance, are stated the differences of two patent-nickel standards of 1 ohm (No. 22 and No. 23), as observed at different times :—

TABLE IV.

Date	Difference of No. 23–No. 22 in Ohms	Date	Difference of No. 23–No. 22 in Ohms
1890		1891	
21/VI.	0·00012	9/V.	0·00009
11/VII.	11·5	30/VII.	10
25/XI.	11·5	1892	
1891		1/III.	8·7
29/I.	10	21/V.	9·5
2/V.	8	19/VII.	9·4

On the other hand, from comparisons of the sum of No. 22 and No. 23 with four different mercury standards (I., II., III., and IV., each of about 1 ohm), I proved that the absolute values of the two standards had remained constant within the errors of observation, as the following numbers show :—

TABLE V.

—	Values of No. 23 at 20° C. deduced from Comparisons of No. 22 +No. 23 with the Mercury Standards				
Date	II.+III.	I.+III.	III.+IV.	I.+IV.	I.+II.
Nov. 1890	—	0·99990	0·99986	0·99988	—
Feb. 1891	0·99989	88	—	—	—
June 1892	85	88	—	—	0·99986
July 1892	89	89	—	—	89

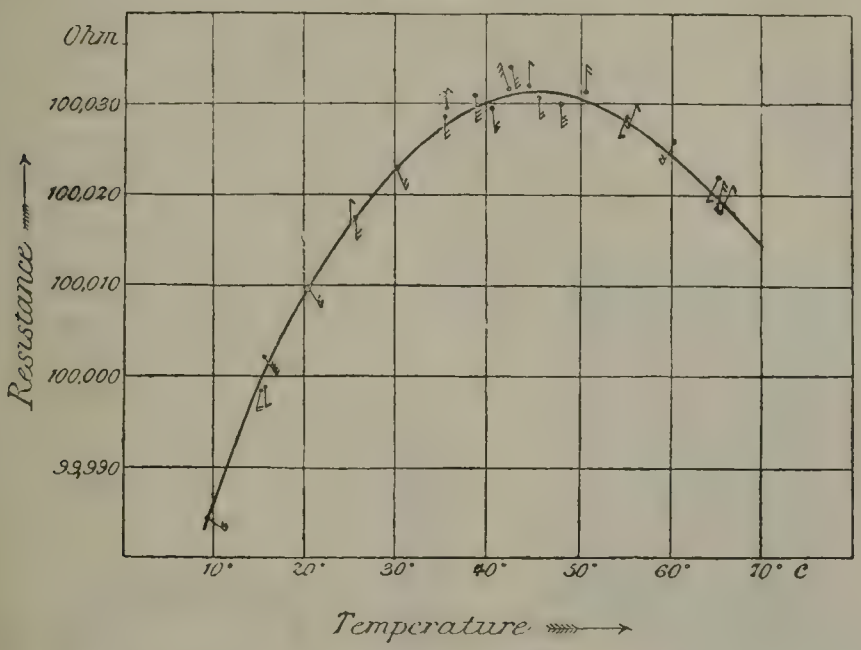
The 'patent-nickel' would therefore be a material well fitted for resistance-coils. A large number of alloys were also examined, consisting of nothing but nickel and copper. An alloy containing about equal amounts of each metal was found to have an extremely small temperature-coefficient, the latter amounting to about 0·003 per cent. per Centigrade degree as against 0·02 per cent. for patent-nickel. Unfortunately, however, the thermo-electric effect of these alloys against copper is very high. For the alloy just mentioned (consisting of 50 per cent. Cu and 50 per cent. Ni, called 'constantan') it amounts to nearly forty microvolts per degree Centigrade, considerably surpassing the thermo-electromotive force of most of the usual thermo-junctions, like iron—German-silver, for instance. This high thermo-electric effect evidently constitutes a considerable drawback, as the connecting pieces have to be made of copper.

On the whole our experience has led us to the conclusion that for standards such alloys do best which, besides copper and nickel, also contain manganese. A few years ago Mr. Weston, of Newark, U.S., discovered that alloys containing manganese possess a very small temperature-coefficient, and that it is even possible to obtain metals with negative temperature-coefficient in this way. I am not aware how far this discovery has been practically taken advantage of in the United States. After hearing of Weston's observation the further investigation of manganese alloys was taken up at the Reichsanstalt, and we obtained very interesting results.

The alloy, which is now being regularly manufactured and brought out under the name of manganin, consists of 84 per cent. of copper, 12 per cent. of manganese, and about 4 per cent. of nickel. As the observations made by me for the last two years in the Reichsanstalt have shown, this is a most appropriate material for standard resistances.

The general character of the resistance-variations of manganin with temperature may be best understood from the diagram (fig. 1), in which

Fig. 1.



temperatures are taken for abscissæ, and the resistances of a hundred-ohm standard are plotted as ordinates. In this case up to 40° C. the temperature-coefficient is positive, the absolute value, however, being very small, as the following table of the mean linear coefficients between the temperatures stated in the first column shows :—

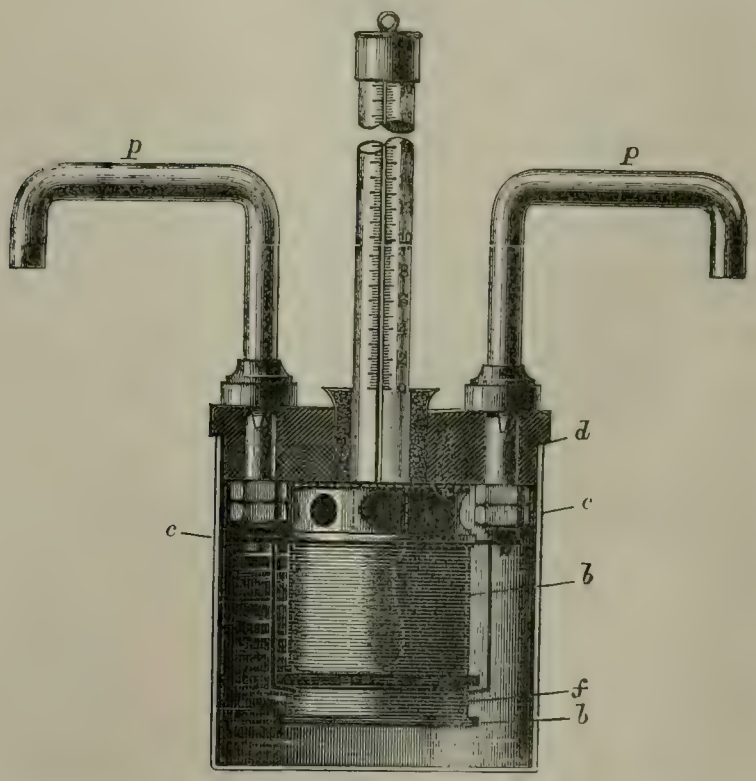
Table VI.

Range of Temperature	Mean Linear T.C.	Range of Temperature	Mean Linear T.C.
10° to 20°	$+25\times10^{-6}$	45° to 50°	-1×10^{-6}
20 „ 30	+14 „	50 „ 55	− 2 „
30 „ 35	+ 4 „	55 „ 60	− 4 „
35 „ 40	+ 3 „	60 „ 65	− 5 „
40 „ 45	+ 1 „		

For most purposes the variability of resistance with temperature may now, indeed, be quite neglected. As a matter of fact, very elaborate and sensitive methods are required to demonstrate the existence of any temperature-coefficient at all. On raising the temperature beyond 50° C. the resistance attains a maximum, thence to diminish again. In this latter part of the curve we therefore actually have a negative temperature-coefficient.

In order to show that at the same temperature the resistance always returns to the same value—in other words, that there is no hysteresis in the relation between those two quantities, some points of the curve were determined with temperatures descending from 70° C., whereas others were obtained with ascending temperature. This process was repeated several times. The spots marked ⊙/ correspond to descending, the spots marked ⊙\ to ascending temperature, and the points belonging to the same series of observations have the same sign. All points are extremely close to the same continuous curve, and it is quite obvious that this curious behaviour is a constant physical quality of the material. Of course such a resistance-coil must have been artificially aged before the beginning of the observations; it was indeed heated during five hours at a temperature of about 140° C. Otherwise, as I mentioned before, a progressive process of decrease of resistance through annealing would superpose upon the regular variation of resistance according to the curve. It is true that this maximum resistance-point does not always occur at exactly the same temperature for wires of different size; it is well known that the electrical constants of all resistance alloys change slightly with the gauge of the wire. But it is also true that the maximum resistance-

FIG. 2.



point of manganin of a thicker size—say 1 mm.—occurs, as a rule, at about 30° C., and so at ordinary temperatures the temperature-coefficient is even less than for this particular specimen of wire.

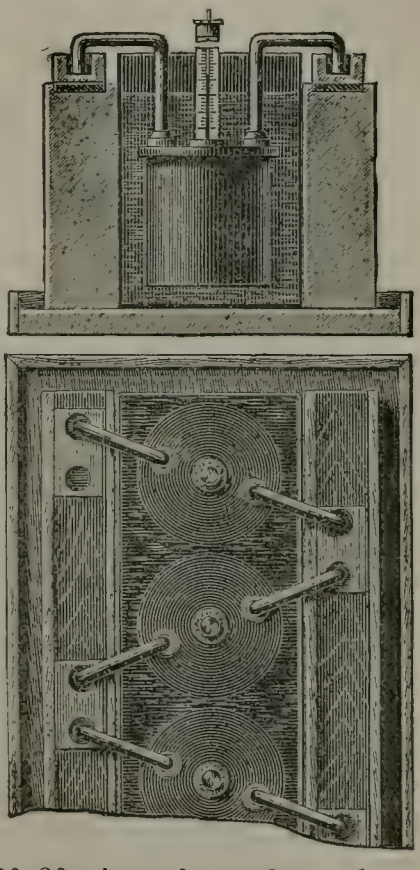
The material is very soft, and can be drawn to the finest gauges; but

it must not be annealed in free air, because the manganese then would oxidise, and the qualities of the material would be altered. Thus it is not possible to buy, for instance, a wire, say 1 mm. thick, and to draw it down to the required gauge without taking proper precautions.

In concluding, I will very briefly refer to the construction of our wire-standards—for instance, to a standard of one ohm (fig. 2).[1]

The double silk-covered wire is wound on a metal bobbin, *b b*, which is previously covered with a thin piece of silk, coated with shellac varnish and heated, in order to secure good insulation. The bobbin can be screwed to the ebonite disk *d*, but it is not fixed to it before the accurate adjustment of the resistance. The resistance of the wire must be 1–2 per cent. larger than one ohm to begin with; then it is wound on the bobbin, heavily coated with shellac varnish, and heated in an air-bath at a temperature of 140° C. during about five hours. By this procedure we obtain, as already stated, very constant resistances; further, the shellac is melted at this temperature, and becomes after cooling a hard, highly insulating mass, which at the same time protects the wire against any chemical action.

FIG. 3.



To the ends of the wire are previously soldered with silver two small copper rings. The exact adjustment is made by means of a fine wire-resistance, *f*, of 100–200 ohms put in multiple arc with the thick wire. A comparatively great length of this fine wire corresponds to a very small change of the whole resistance, and so it may be easily adjusted to a few thousandths per cent. Then the small rings at the ends of the two wires are screwed together and soldered to the stout connecting pieces, *p p*. A wide brass case, *c c*, serves to protect the wire.

In taking observations the resistance is put in an oil-bath (fig. 3); the temperature of the wire may then easily be determined, and besides that, there cannot exist any thermo-electric force between the two solderings. It is a matter of fact that the thermo-electric force of manganin against copper is very small indeed; it amounts only to 1·5 microvolt for 1° C.; the corresponding value for other resistance materials is generally 20–30 microvolts. We see that even in this respect the manganin is much preferable.

The construction of standards of 0·1 ohm, and, on the other hand, of 10, 100, 1,000 ohms and more, is essentially the same as described. Of course there is no multiple arc to those of 10 ohms and more.

As to the constancy of manganin resistances I will quote a few figures. Table VII. refers to a resistance which is used to determine

[1] See Dr. K. Feussner, *Zeitschrift für Instrumentenkunde*, 1890, p. 6.

the electromotive force of the standard Clark cells with the silver-voltameter. Thus very often (more than fifty times) a current of about one half of an ampère was passed through it for one hour each time. At 18° C. I found the following values :—

TABLE VII.

Date	Resistance in Ohms	Date	Resistance in Ohms
6/I. 1890	2·9998	22/VII. 1891	2·9996
15/IV. „	99	9/II. 1892	98
12/II. 1891	98	17/VII. „	96

Again, in the following table are stated in microhms the differences in the resistance of four manganin standards (No. 148 to No. 151) of one ohm. The numbers marked * were observed by Drs. Kreichgauer and Jäger, using Kohlrausch's differential galvanometer method, the others by myself, using a Wheatstone's bridge arrangement.

TABLE VIII.

—	December 1891*	February 1892	July 1892*	July 1892
No. 148–No. 149	-121×10^{-6} Ohms	-124×10^{-6} Ohms	-117×10^{-6} Ohms	—
-No. 150	−135	−135	−129	—
No. 151	− 80	− 79	− 86	—
No. 149–No. 150	− 14	− 15	− 12	−16
-No. 151	+ 41	+ 39	+ 31	—
No. 150–No. 151	+ 55	+ 53	+ 43	+48

Measurements were also made of these standards shortly after their construction in July 1891, but not with quite the same accuracy as the later ones. Anyhow, they show, in connection with numerous comparisons of the four coils with other standards, which were checked by mercury resistances, that the manganin coils were constant for the space of one year within a few thousandths per cent.

The patterns referred to are intended to be standards of resistance. On the other hand, resistances of 0·01, 0·001, and even 0·0001 ohm are used for measuring large currents up to a few thousand ampères by compensating the potential difference which the current itself produces in flowing through the resistance. These resistances consist of manganin plates, which are soldered with silver to stout copper bars. The dimensions of the plates are chosen in such a manner that the value of the resistance is too small to begin with, and the definitive adjustment is arrived at by boring small holes in the plates; the latter are again coated with varnish in order to protect them against any chemical action of the oil, and so on. For uncovered wires, as they are used, for instance, in bridges, or in technical resistances, the manganin is perhaps not so appropriate as the alloys commonly used. For all other resistances, however, we think it is the best alloy hitherto known, because it facilitates the electrical measurements, and brings them to a higher degree of accuracy than was formerly attainable.

APPENDIX V.

On the Clark Cell.[1] *By* Dr. KAHLE.

In connection with the report of the Committee I beg to call your attention to some researches I made, by order of the Physico-Technical Institute at Berlin, on Clark cells. The time is too short for communicating my measuring methods and results in full extent; I can only give you a short summary of the chief points.

I used in my researches Lord Rayleigh's H form, the positive electrode being mercury once distilled, the negative an amalgam containing ninety parts of mercury and ten parts of zinc. The last was poured into the vessel as a hot liquid, and solidified on the bottom. The paste, which covers the positive electrode, is made by grinding together mercurous sulphate, mercury, and a mixture of crystals and concentrated solution of zinc sulphate. No heat was used in preparing this paste. The mercurous sulphate was bought, and contained, according to chemical analysis, no foreign ingredients. The zinc sulphate was made basic by boiling with rods of metallic zinc; after cooling, the dissolved oxide of zinc precipitates, and with it the oxides of the metals more negative than zinc. For oxidising the ferrous sulphate, which is always present in commercial zinc sulphate, a small current was sent between two platinum electrodes through the boiling basic solution; the ferrous sulphate was changed by the generated oxygen into ferric oxide, and fell out. The H cells set up with these materials showed a great agreement in their E.M.F.'s. I never found a difference greater than $\frac{1}{10000}$th of a volt between the E.M.F. of any two of them.

The next point I studied was the influence of the impurities in the different materials composing the cell on the E.M.F., because on the one hand it is well known that the smallest impurity of the mercury alters very distinctly the E.M.F., and on the other hand the mercurous sulphate I bought never contained impurities of a remarkable amount, and different samples always had the same qualities; I only investigated, as the most important matter, the impurities of the zinc and its sulphate. It was found that the foreign ingredients of the zinc sulphate are of very little importance, and that only the presence of free acid in the above-described cleaning process, the result of boiling with metallic zinc, alters the E.M.F. in a considerable degree. Among the impurities of the zinc only those caused by metals more positive than zinc are of importance; the zinc may contain considerable quantities of the negative metals without any alteration of the E.M.F. I conclude that the impurities of the zinc are of greater importance. If we use it in the form of rods amalgamated on the surface, it seems to be a great advantage to dissolve the zinc in mercury, using it then as a solid amalgam.

The following are the values I found by a great number of observations for the temperature coefficient of different forms of cells, measuring between 10° and 30° in rising and decreasing temperature. The figures here given are the mean values of some cells of the same form, treated in the same manner:—

[1] For a detailed account see *Zeitschrift für Instrumentenkunde*, April 1892, and *Electrotechnische Zeitschrift*, Heft 30, 1892.

TABLE IX.

Form of the cell	Temperature-coefficient	Mean difference between calculated and observed values of E.M.F.	Mean difference between the E.M.F. of the different cells and that of the mean of several H cells used as standards
		The unit being $\frac{1}{100000}$th of a volt	
H cell set up in Lord Rayleigh's manner	$0{\cdot}000812+0{\cdot}000013\,(t-15)$	12	+3
H cell, the paste covering both electrodes	$0{\cdot}000774+0{\cdot}000020\,(t-15)$	12	+7
A new form for research purposes, the paste covering both electrodes	$0{\cdot}000791+0{\cdot}000017\,(t-15)$	9	+9
The cell issued hitherto by the German Reichsanstalt	$0{\cdot}000806+0{\cdot}000006\,(t-15)$	30	−29

The mean value of the temperature-coefficient, therefore, would be

$$0{\cdot}000796+0{\cdot}000014\,(t-15).$$

Lord Rayleigh has given the following values for the two different cells he investigated :—

$$+0{\cdot}000827+0{\cdot}000018\,(t-15)$$
$$+0{\cdot}000740+0{\cdot}000016\,(t-15)$$

the mean being

$$+0{\cdot}000783+0{\cdot}000017\,(t-15).$$

I suppose, for practical purposes, the values found by Lord Rayleigh and by me are identical.

The most important matter is to obtain the absolute term of the E.M.F. For the purpose I used a measuring arrangement similar to Lord Rayleigh's. The current, which produces on the terminals of a known resistance a pressure equal to that of the Clark cell, was obtained by the silver voltameter. It was found that the same current deposits the more silver the more oxide of silver is dissolved in the solution of the nitrate. I made a solution of nitrate crystals, and boiled a part of it a long time with oxide of silver; the deposit obtained with this basic solution was about $\frac{5}{10000}$ths greater than that with the original solution. Therefore, using a certain number for the equivalent of silver, there will be a little uncertainty of some parts in 10,000 in measuring currents by the deposit of silver. Now, as first shown by Professor Schuster, and also proved by me by a good deal of experimenting, the deposit, when the voltameter is in vacuo, is about four parts of 10,000 greater than in ordinary air. But the absolute value of the E.M.F. is not touched by

this fact, because making the electrolysis in this manner one has certainly to take a greater figure for the equivalent, and therefore the ratio between the unit and the measured amount of current remains the same. The following figures are given by taking one ohm=1·063 S.U., and by assuming that a current of one ampère strength deposits in an hour 4·0259 grammes; the last figure exceeds that given by the Board of Trade only by six parts in 100,000. I found by some thirty experiments the E.M.F. of the H cells, set up with clean materials in the above-described manner, as 1·4332 volt at 15°, and am sure that, when using the same arrangement of the silver voltameter, this value will be right by five parts in 10,000 if the equivalent is certain to this extent. If I express the value given by Lord Rayleigh for the cells of the original Clark's form in this unit, it is 1·4346 volt at 15°. Lord Rayleigh finds the E.M.F. of this H cell a few ten-thousandths of a volt greater than that of the old form. Therefore it would, perhaps, be 1·4350 volt at 15°.

Recently Mr. Glazebrook has made a new determination, and finds the E.M.F. of the original Clark cell, in the above fixed units, to be 1·4342 volt at 15°. He has also compared H cells set up by me, and now brought to England, and finds their E.M.F. smaller by $\frac{4}{10000}$ths of a volt than that of the original form. Therefore the E.M.F. of the H cell is 1·4338 volt at 15°. This last value and that found by me are in good agreement. It is to be noted that the anodes and cathodes in my voltameters are much smaller than those in the English ones.

It may be mentioned here that the mean E.M.F. of four H cells set up in the same manner as before, but containing, in accord with Professor Carhart's directions, a solution of sulphate of zinc, saturated at 0°, was found to be 1·442 volt at 15°, using the same units as above.

It only remains to give some directions on the best form of Clark cells. I suppose it will be good to distinguish such cells which are to remain as standards in the laboratories and are used by their maker, and such as are to be used for practical purposes. These do not need to have the same degree of accuracy, but they must be able to be carried about. In the Board of Trade memorandum the original Clark cell is adopted as the standard; but I think Lord Rayleigh's H form gives more accuracy and is easier to set up. In the old form not all the parts of the zinc rod are in saturated solution, and therefore the value of the E.M.F. will be a little uncertain. Another disadvantage is that parts of the zinc rod may fall down in the mercury, and will so produce a considerable variation of the E.M.F. On the other hand, the electrodes of the H form are always in concentrated solution, and there is no possibility of parts of the negative electrode coming over to the positive one. I have set up about sixty H cells, and have found no difficulty, when using carefully cleaned materials, to keep the difference of the E.M.F. of the single cells under a ten-thousandth of a volt.

To construct cells for practical purposes which will stand carriage, the most simple way is to separate the two electrodes by a porous wall. I can show here such a cell of a form constructed by Dr. Feussner, and issued hitherto by the German Reichsanstalt. The positive electrode is an amalgamated platinum plate with the surrounding paste in a porous vessel of clay. The zinc rod forming the positive electrode is on the upper part protected by a glass tube; the lower part is blown rectangularly and covered with crystals of sulphate of zinc. The whole glass vessel is filled with a concentrated solution of this salt. The E.M.F. of

such cells is about $\frac{3}{10000}$ths of a volt higher than that of the H cells. The agreement of different cells of this form is very sufficient for practical purposes; the difference between the E.M.F. is always smaller than $\frac{1}{10000}$th of a volt. The only disadvantage of this form is that its E.M.F. does not follow quickly the alterations of temperature; but I suppose one could improve that by diminishing the size of the cell.

We endeavoured in the Reichsanstalt to make Lord Rayleigh's H form transportable on account of its good qualities, and to do this without introducing foreign substances as porous walls. The investigations in this direction are not yet finished, but I am able to exhibit a cell which was constructed for this purpose and seems to be good. The positive electrode is formed by an amalgamated platinum plate fixed on a wire of the same metal, which is melted in the bottom of one of the two tubes forming the vessel. The negative electrode is formed by the 10 per-centage zinc amalgam solidified on the bottom of the other tube, and also connected with a platinum wire melted in the glass. The whole vessel is filled with paste and closed by a glass stopper perforated by a thermometer, of which the bulb is within the vessel. Such a cell can be turned without any danger, and is suitable for transport. The E.M.F. is about $\frac{1}{10000}$th of a volt smaller than that of the H cells; the disagreement between the E.M.F.'s of different cells constructed in similar manner does not exceed $\frac{2}{10000}$ths of a volt. But before using such cells for practical purposes, they must be observed for a longer time till one is sure that their behaviour will not be altered by age.

These are the principal results obtained recently in the Reichsanstalt on this matter. Some of them will be already known here; but I hope to have given new proof that the Clark cell is a very accurate standard for E.M.F., and a good measuring instrument for practical purposes.

APPENDIX VI.

On the Values of certain Standard Resistance Coils.
By R. T. Glazebrook, *F.R.S.*

In the report of the Committee for 1890 it was stated that during the early part of the year small changes had taken place in the values of some of the old B.A. standards, which had been subjected to a very low temperature early in that year. These coils have been compared together at intervals since that date, and the following tables will show that at the temperatures given there is no indication of any further change. The difference between the coils and the standard coil flat is given in bridge wire divisions. The value of one bridge wire division is about ·00005 ohm.

The first few lines in Tables X. and XI. give the values of the differences observed in 1890. These are followed by those of the more recent observations which were taken at a temperature of about 16°.

These observations are sufficient to show that there has been no appreciable change in the relative values of these coils.

The observations on the legal ohm standards given in Table XI. lead to the same conclusion.

TABLE X.—*Showing the Differences between the Platinum Silver B.A. Units in* 1890 *and in* 1892.

Date	Temperature	Flat−F	Flat−G	Flat−H
May 1890 . . .	14·4	−3·5	21·5	18·3
June 1890 . . .	16	−3·2	22·2	17·8
August 1890 . . .	16·5	−3	22·6	18
July 23, 1892 . . .	16	−3·7	21·6	18·4
July 24, 1892 . . .	16	−3·5	22	18·3
July 27, 1892 . . .	16·2	−3·2	21·6	18·3

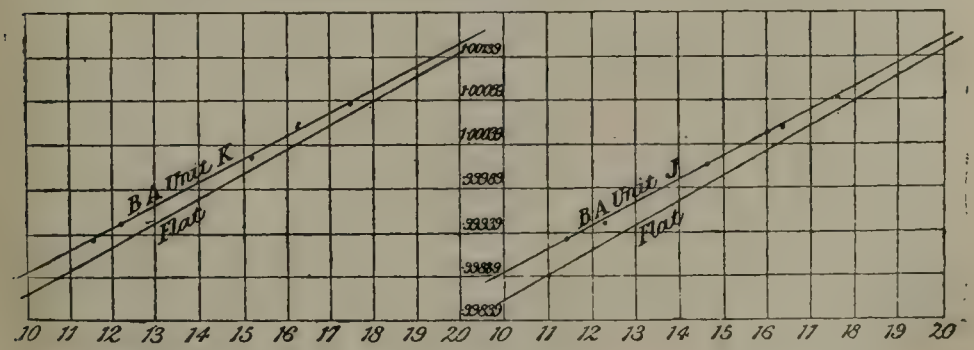
TABLE XI.—*Giving Differences in Bridge Wire Divisions between the Legal Ohm Standards and Flat.*

Date	Temperature	100−Flat	101−Flat
August 1890 . . .	15·7	216·7	206·6
November 1890 . . .	15	217·2	206·7
January 1891 . . .	11·6	216·1	206·8
July 25, 1892 . . .	16·3	215·6	205·8
July 27, 1892 . . .	16·1	216	206·3

In November 1890 two new coils marked J and K were made of platinum silver wire, supplied by Messrs. Elliott Bros. The wires of the coils are wound in a loose spiral inside the case, being secured at intervals by silk threads to an ebonite central stem. They are thus in contact with air only, and there is no paraffin inside the case. It was hoped in this way to secure freedom from the strains set up by changes of temperature in the paraffin, which appeared from the results given in the 'Report' for 1890 to have some connection with the changes of resistance there described.

The results are shown in fig. 4. From the six observations for each coil there recorded it is clear that there has been no change during the time for which the observations have lasted.

FIG. 4.—Showing the values of the B.A. Units Flat, J and K, from observations between November 1890 and July 1892.



The vertical divisions are ·0005 B.A.U.
The horizontal divisions are 1° C.
Flat = 1 B.A.U. at 14°·8. Temp. Coeff. ·00027 (Fleming's observations, 1876).
J = 1 B.A.U. at 14°·. Temp. Coeff. ·000260.
K = 1 B.A.U. at 14°·15. Temp. Coeff. ·000261.

Two observations were made at a much lower temperature, and these would seem to indicate a slightly less temperature-coefficient than is shown by the observations between 10° C. and 20° C.

The values of the two new coils in B.A. units between temperatures of 10° and 20° are given by

$$J=1+\cdot000260(t-14).$$
$$K=1+\cdot000261(t-14\cdot15).$$

We may thus conclude that during the past two years there has been no relative change in the values of the platinum silver unit standards of the Association.

Four of these are the original standards made in 1865–67; two others were made by Messrs. Elliott Bros. in 1885, and the last two by the assistant at the Cavendish Laboratory from wire supplied by Messrs. Elliott in 1889.

APPENDIX VII.

On the Standard Condensers of the Association, and on Certain Resistance Coils. *By* R. T. GLAZEBROOK, *F.R.S.*

The report of the Committee for 1890 contains as an appendix a very full account of the tests on the air condensers belonging to the Association. It was there stated that while the insulation resistance of No. I. was very high, that of No. II. was not completely satisfactory; No. II. was therefore taken to pieces and set up fresh. Its capacity and also that of No. I. were determined afresh, using the commutator method described in the previous paper.

The following values were found:—

TABLE XII.

Date	Capacity in Microfarads	Mean of each Series
	CONDENSER No. I.	
Dec. 23, 1890 . . .	·021059	
„ „ . . .	·021052	·021050
„ „ . . .	·021046	
Dec. 29 „ . . .	·021044	
	CONDENSER No. II.	
Dec. 23, 1890 . . .	·021396	
„ „ . . .	·021392	·021395
„ „ . . .	·021399	
Dec. 23, 1890, afternoon	·021365	
„ „ „ .	·021399	·021389
„ „ „ .	·021403	
Dec. 29 „ „ .	·021381	
„ „ „ .	·021409	·021390
„ „ „ .	·021389	

Mean of the whole, ·021391 microfarad.

The different values in each series correspond to different rates of revolution of the commutator.

The value found originally for the capacity of No. I. was ·021024 microfarad; it would appear therefore that it may be slowly increasing; the capacity of No. II. has been changed by being taken to pieces, and from ·022515 to 021391.

The two condensers were also compared, directly assuming the value of No. I. to be ·021050; that of No. II. was found to be ·021390—practically the same value as that given by the commutator.

As a further check on the values a mica condenser was compared with the two in the usual way. The values found were:—

TABLE XIII.

Date	In Terms of I.	In Terms of II.
Dec. 29, 1890 . . .	·5017	·5013
Jan. 1, 1891 . . .	·5013	·5012

In March 1892 the insulation of the condensers was tested by the Secretary and Mr. A. S. Bowley; they were both found to lose rather less than $\frac{1}{600}$ of their charge per one minute. A divided condenser, Elliott No. 144, No. 3, was compared; the results are interesting as showing the effect on the capacity of the time of charging, and are given in Table XIV.

TABLE XIV.

Nominal Value	Time of Charging, in seconds	Value in Terms of I.	Value in Terms of II.
·05	0	·05022	
	5	·05072	
	10	·05080	
·05+	0	·05055	
	5	·05106	
	10	·05109	
·2	0	·1988	·1981
	2	·1999	·2002
	5	·2007	·2009
	10	·2010	·2013
	20	·2012	
·2+	0	·2003	
	2	·2018	
	5	·2027	
	10	·2033	
	20	·2039	
	30	·2046	
·5	0	·5032	
	2	·5058	
	5	·5078	
	10	·5081	
	20	·5092	

The first observation in each case marked as 0^s was made by con-

necting the galvanometer, and then momentarily making the battery circuit for a very small fraction of a second. The observations on the condenser ·2 show that there has been no appreciable change in the relative value of Standards I. and II. The observations throughout are accurate to about one part in 10,000.

During the process of the work Mr. Bowley compared several of the resistance boxes of the Association together. As these are used as standards in many experiments it will be useful to put the results on record.

Box Elliott 1253 is a Wheatstone's bridge box of platinum silver in legal ohms, said to be right at 17° C. Assuming that the two 1,000-ohm coils of the bridge are equal, and the experiments showed no appreciable difference, the following values were found for certain coils in terms of a nominal 10,000 ohms taken from 1253.

The temperature of all the coils was about 15°·6 C.

Thus the box Elliott 1825 is right at about 4° below the box 1253, while the box Nalder 1870 is right at about 1°·5 below 1253.

TABLE XV.

Nominal Value	Value found
Elliott 1825.	
10,000	10,012
20,000	20,024
30,000	30,034
40,000	40,049
Nalder 1870.	
100,000 No. 1	100,042
,, ,, 2	100,044
,, ,, 3	100,050
,, ,, 4	100,034
,, ,, 5	100,042
,, ,, 6	100,042
,, ,, 7	100,052
,, ,, 8	100,032
,, ,, 9	100,047
,, ,, 10	100,052

APPENDIX VIII.

On the Values of certain Standards of Resistance and Electromotive Force sent from Berlin for Comparison with the British Association Standards. *By* R. T. GLAZEBROOK, *F.R.S.*

Towards the end of July Dr. Lindeck, of the Physikalische Electrotechnische Reichsanstalt at Berlin, brought to Cambridge three resistance coils of nickel-manganese-copper alloy in order to compare them with the British Association standards. Experiments to determine the value of these coils in terms of the resistance of mercury are in progress

at Berlin; when they are completed a comparison of the British Association units with the mercury standards of the Reichsanstalt will become possible.

A fourth coil, constructed for the Berlin Reichsanstalt by Messrs. Elliott Bros., was also tested. Table XVI. contains the results of the comparison:—

TABLE XVI.

No. of Coil	Date	Temp.	Value in B.A. Units	Mean Value of Series
Wolff, 150	July 25	16·5	1·01118*	1·01118 at 16°·7
	„ 27	17	1·01116*	
	„ 25	16·5	1·01119	
	„ 26	16·3	1·01119	
	„ 27	17·1	1·01120	
Wolff, 139	July 25	16·5	1·01110*	1·01112 at 16°·7
	„ 27	16·9	1·01112*	
	„ 25	16·5	1·01110	
	„ 26	16·3	1·01114	
	„ 27	17·1	1·01110	
Wolff, 147	July 25	16·5	1·01112*	1·01113 at 16°·7
	„ 27	16·9	1·01112*	
	„ 25	16·5	1·01113	
	„ 26	16·3	1·01112	
	„ 27	17·1	1·01115	
Elliott, 250	July 25	17	1·01107*	1·01107 at 17°
	„ 27	17	1·01107*	
	„ 28	17	1·01108*	
	„ 28	17	1·01108	

In the experiments marked thus * a considerable length, 200 cm., of the bridge wire was used. An error of 1° in the temperature of this would produce an error of ·00003 in the result. In reducing the results the temperature of the bridge has been taken as 18°, the value given by a thermometer laid alongside the wire on July 28. In the other experiments a coil of 100 ohms was put in multiple arc with the Berlin standard, and the difference of the combination and the British Association units was found. The length of bridge wire was very small, so that an exact knowledge of its temperature was not wanted, while the 100-ohm coil was known with all the necessary accuracy.

Another set of comparisons, leading to results which do not differ from the above by more than ·00003 British Association unit, were made by Dr. Lindeck, using apparatus he had brought from Berlin; but a complete discussion of the whole can best be given when the values of the Berlin coils in terms of the mercury standard have been found.

Dr. Lindeck also brought four Clark cells. Of these two, Nos. 69 and 71, were of the pattern described by Dr. Kahle ('Electrotechnische Zeitschrift,' July 22, 1892; 'Zeitschrift für Instrumentenkunde,' April 1892). The mercurous sulphate is enclosed in a porous pot. The zinc dips among the crystals of the zinc sulphate, its end being bent so as to be horizontal. The vertical portion of the zinc is covered with a glass tube, so that the horizontal part alone is effective.

The other two, Nos. 12 and 29, were H cells of the pattern described by Lord Rayleigh.

These cells were compared with the standard at the Cavendish Laboratory with the results shown in Table XVII., which gives the differences between the four cells and the standard in hundred thousandths of a volt.

TABLE XVII.

—	Values of Berlin Cell—Standard in ·00001 Volt		
Date	July 26	July 27	July 29
Temperature	16°·1	15°·9	15°·9
Cell No. 69	−15	−18	−14
„ 71	−11	−15	—
„ 29	−36	−35	−36
„ 12	−39	−38	−39

On July 29 cell No. 71 had been taken away. Dr. Kahle kindly determined the differences between No. 69 and each of the other cells before they left Berlin. Values for these same differences can be obtained from Table XVII.

We thus get Table XVIII.

TABLE XVIII.

Differences between Cell No. 69 and the others sent from Berlin			
Date and Place of Observation	No. 71	No. 12	No. 29
July 19, 1892, Berlin	−2	29	29
„ 20 „ Berlin	−4	28	25
„ 21 „ Berlin	−4	25	26
July 26, 1892, Cambridge	−4	21	24
„ 27 „ Cambridge	−3	19	20
„ 29 „ Cambridge	—	22	25

Thus the relative values of the cells as found at Cambridge are practically the same as those found at Berlin. Moreover, taking the E.M.F. of the Cambridge standard as 1·4342 volt at 15° C., that of the Berlin cells, with porous pots, is 1·43405, and of the Berlin H cells about 1·4338.

The value actually found by Dr. Kahle for the E.M.F. of the porous pot cells is 1·4336 volt, so that the agreement is satisfactory. In all the above it has been assumed that the resistance of 106·30 centimetres of mercury is 1 ohm, and that the amount of silver deposited per second by a current of 1 ampère is ·001118 gramme.

The H form of cell in all cases examined at Berlin has a slightly lower E.M.F. than those with the porous pots, the difference being about ·0003 volt.

Report of the Committee, consisting of Dr. JOHN KERR, Mr. R. T. GLAZEBROOK, Lord KELVIN, *and* Professor A. W. RÜCKER, *on Electro-optics.*

THE Committee report that Dr. Kerr has continued his work on electro-optics during the year. His results are given in the appendix to this report.

APPENDIX.

On Dispersion in Double Refraction due to Electric Stress.
By Dr. JOHN KERR.

The object of the experiments was to find whether the optical effect of electric stress varies with wave-length. The only dielectric examined was CS_2, and the cell was that described in the 'Phil. Mag.' for March, 1880. The two nicols at the ends of the cell were placed with principal sections parallel, and at 45° to the lines of force. Immediately after the second nicol came a spectroscope, which received no other light than that which passed through the two nicols and the uniform part of the electric field. The lunette of the spectroscope was focussed, and directed so that one of Fraunhofer's lines passed through the intersection of the wires, and the instrument was untouched until the end of the measurement.

When the electric force is applied, the spectrum darkens; and as the potential rises through a sufficient range, a black fringe passes gradually over the spectrum, entering at the violet end, and leaving at the red. This fringe we know to be the place of phase-difference π, or of retardation-difference $\frac{1}{2}\lambda$, of the two component rays.

The one measurement made in each case was that of the potential at which the black fringe was bisected by the above-mentioned Fraunhofer's line. The following table contains the results of the two sets of measurements last taken. In each of the last three divisions of the table the first two lines of numbers correspond to the two sets of measurements, and the third line to their averages. The quantities represented by the numbers are indicated in the first column, V standing for potential, Q for corresponding optical effect, and Q′ for the value of Q when V=180.[1]

—	C	D	F	G (hydrogen)
Wave-lengths	6562	5892	4860	4340
$Q=\frac{\lambda}{2}$; $V=$	194 194 194	180 179 179½	155 156 155⅓	142 143 142½
V=180; $Q'=$	565 558 562	589 589 589	655 640 647	697 680 688
$Q'\sqrt{\lambda}=$	457 451 455	452 452 452	456 446 451	459 448 453

[1] The values of Q′ are calculated from those of Q by the law of squares, this law being verified for the three monochromatic lights G, F, D with the present apparatus and arrangements, and through a range of effect equal to λ.

From the fact that Q′ undergoes a regular increase from the red end of the spectrum to the blue, and from the approximate equality of the lowest line of numbers, it may be inferred—

(1) That the optical effect of electric stress in a given medium (CS_2) increases as the wave-length diminishes.

(2) And more definitely, that the optical effect varies exactly or very nearly in the inverse ratio of the square root of wave-length.

Eighth Report of the Committee, consisting of Sir G. G. Stokes (*Chairman*), Professor A. Schuster, Mr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain W. de W. Abney, Mr. G. M. Whipple, Professor McLeod, *and* Mr. G. J. Symons, *appointed for considering the best methods of recording the direct Intensity of Solar Radiation.* (*Drawn up by* Sir G. G. Stokes.)

The work of the Committee during the past year has been confined to an examination, both experimental and theoretical, of Balfour Stewart's second actinometer when used as a dynamical instrument. Actinometers may be divided into two classes, which may conveniently be denominated *dynamical* and *statical* respectively. In those of the dynamical class the mercury or other fluid employed is examined while the head of the column is in motion, in consequence of the exposure being varied by suitable manipulation, and readings of the column are taken at chosen times, or else the times are noted when the top of the column reaches chosen readings. In the statical class the instrument is allowed to attain its permanent state, subject of course to a secular change, such as that due to the varying altitude of the sun, and the results are deduced from the stationary readings of two or more thermometers. Herschel's, Hodgkinson's, and Stewart's first actinometers are examples of the dynamical kind; the black bulb thermometer, Violle's actinometer, and Stewart's second actinometer, when used as he intended, are examples of the statical class.

Stewart's second actinometer has been already described (see Reports of the Association for 1886, p. 63, and 1887, p. 32), but to save the trouble of reference it may be well briefly to mention that it consists of an envelope of thick copper, closed on all sides except as regards a small hole to allow the sun's rays to enter, and one to allow the stem of the central thermometer to pass through. In the actual instrument the envelope is cubical, and its temperature is determined by three thermometers, with their bulbs sunk in hollow chambers in the thick metal, two (A, B) in the front face of the cube, or that turned towards the sun, the third (C) in the back face. The internal thermometer (D) has a lenticular bulb, which is mounted so that it lies at the centre of the cube, or nearly so, and has its plane perpendicular to the incident rays. The copper cube is surrounded by a thick coating of felt, and this by a covering of thin brass. The object of this arrangement is to make the temperature of the copper cube sensibly the same all round, and at the same time to prevent it from changing more than very slowly when the instrument is exposed. The thermometers A, B, C were graduated to degrees, D to half-degrees, all Fahrenheit.

With a view to increasing the effect of the radiation from the sun on the thermometer D its bulb was ordered to be of green glass of a particular kind. This, as we ascertained from Mr. Casella, who made the instrument, occasioned a great deal of trouble, as not only had a pot of green glass to be made specially for the purpose, but many thermometers broke in the process of construction, the fracture taking place at the junction of the green glass of the bulb with the colourless glass of the stem. In a future instrument we should not think of encountering these difficulties, since, as will presently appear, our researches led us to the conclusion that little advantage, if any, was gained by the substitution of green for colourless glass in the construction of the bulb.

The principle of the instrument was to make any point of the radiation thermometer (D) look, so to speak, in all directions outwards at an envelope of uniform temperature, except as to directions lying within a very small solid angle (that subtended by the hole), within which the sun's rays were admitted. If the direct rays of the sun had been used the solid angle in question could only be made small on condition of admitting only a very small amount of the sun's rays, which would not have sufficed to raise the temperature of D sufficiently above that of A, B, C. To reconcile the two conditions of allowing the bulb of D to be almost wholly surrounded by the copper envelope, and at the same time permitting a sufficient amount of solar radiation to fall upon it, a lens was introduced, mounted on a stem perpendicular to the front face, to which face the plane of the lens was parallel, and from which the lens was distant by its focal length. In this way the necessary hole in the envelope need hardly be wider than the image of the sun, though it was convenient to allow some margin in order to provide for the contingency of the pointing of the instrument not being very exact. The lens was provided with two diaphragms for optional use, one having twice the area of the other.

The observations which have been taken at intervals during the past year with a view to test the practical working of Stewart's second actinometer have been made by Professor McLeod; the reduction of the observations has been mostly done by the Chairman, with whom also Professor McLeod has been in frequent communication as to the lines of inquiry. In consequence of other engagements, the observations have not yet been subjected to so complete a reduction as the care with which they have been made deserves; but enough has been done to serve as a guide to the inquiry, and to permit of some general conclusions as to the behaviour of the instrument.

As has been already stated, the instrument was intended for use as a statical actinometer with permanent exposure. But it seemed desirable in the first instance to study the march of the thermometers when the instrument was first exposed to radiation from the sun, or the sun's rays were cut off after it had been exposed for some time. This seemed to hold out a better prospect of obtaining a thorough insight into the working of the instrument than if it had been at once used as a statical actinometer; besides which the latter use would have involved some outlay in the way of providing some sort of equatorial mounting and clock movement, and it did not seem desirable to go to the expense of this unless preliminary testing showed that the instrument was likely to be successful when used as a statical actinometer.

The temperature of the case was determined from the readings of the thermometers A, B, C by taking first the mean of A and B, and then the

mean of that and C. It was found, however, that A and B always read almost exactly alike, and C was not usually more than one or two tenths of a degree lower. In any future instrument it would doubtless be sufficient to determine the temperature of the copper case by a single thermometer sunk in one of the side faces, midway between the front and back face.

In spite of the felt packing the temperature of the case was found to change more rapidly when the instrument was exposed to the sun than was to be desired, and Professor McLeod found it an improvement to introduce a screen of tinned iron placed a little distance in front of the front side of the cube, and of course provided with a hole for letting the sun's rays through that were to fall upon the thermometer D. In most of the observations the case thermometers were merely sunk in their holes, the sides of which the bulbs might or might not touch in one or two places. It was feared that in spite of the slowness of the change of temperature of the case, the lagging of the case thermometers might possibly introduce a sensible error. Accordingly the effect was tried of introducing a packing of reduced silver between the bulb of the thermometer and the wall of the cavity in which it was inserted. By packing in this manner one of the thermometers A, B, and leaving the other unpacked, it was possible to judge whether any sensible error was to be apprehended from lagging. It was found that the packed thermometer was a little more prompt, but the difference of temperatures read off was very small, little more than emerging from errors of observation.

In the first regular observation on the march of the thermometers under insolation, the four thermometers were read before exposure, then the instrument was exposed, and the thermometers read at intervals of a minute for a quarter of an hour, by which time thermometer D had become sensibly stationary, having risen 51°·3, while the case thermometers rose about 2°, the excess of D over the temperature of the case rising to 49°·7. The sun was then screened off, and the reading of all the thermometers at intervals of one minute continued for about half an hour. During this time the case thermometers continued slowly to rise, the total rise in the half-hour amounting to 1°·5; the central thermometer fell, pretty rapidly towards the beginning, slowly near the end, till it stood only 0°·4 or 0°·5 above the case thermometers. The sky was very clear, and there were no clouds near the sun; and as the insolation began at XII., 26, the decrease of the sun's altitude during insolation was but small.

It remains to be shown whether, and if so in what way, a measure of the radiation can be obtained from the results.

Let θ be the temperature of the insolated thermometer, T that of the case as measured by the case thermometers, q the coefficient of cooling, the rate of cooling being taken as following Newton's law, r the rate of heating of D due to solar radiation. Then in the time dt the increment $d\theta$ of D's temperature is made up of the gain, rdt, due to radiation and the loss, $q(\theta-\mathrm{T})$, due partly to convection, partly to the excess of the radiation from D to the case over that from the case to D. We have therefore

$$\frac{d\theta}{dt}+q(\theta-\mathrm{T})=r \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If we suppose r and T constant, or subject only to slow secular changes, so that they may be deemed constant in the integration, we have

$$\theta = \text{T} + \frac{r}{q} + ce^{-qt} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Hence if u denotes the excess of temperature of the central thermometer over that of the case, we see from (2), or directly from (1), that u tends to the limit

$$u = \frac{r}{q} = \lambda r, \text{ say} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

when the time t which has elapsed since exposure, or whatever other change it may have been in the disposition of the instrument, is large enough to permit of our neglecting the last term in (2). The constant λ, the reciprocal of q, in (3) denotes a time, which may conveniently be called the *lagging time* of the thermometer D.

Were the actinometer used as a statical instrument the simple expression (3) is all that we should be concerned with. The quantity r varies as the radiation, but involves a coefficient depending on the particular instrument and for a given instrument on the area of the diaphragm used, and on the presence or absence of the quartz plate which is furnished for covering the aperture. The constant q need not be determined, as it is associated with a coefficient depending on the instrument. By itself alone the actinometer gives only the ratio of variation of the radiation. To obtain an absolute measure the actinometer would have to be compared, once for all, with some actinometer which gives absolute results. We believe that the main object which Stewart had in view was to furnish an instrument which might supply a means of detecting possible variations in the intrinsic intensity of radiation from the sun, corresponding, suppose, to the sun-spot period; and for this object the same instrument would be employed throughout, so that we should not be concerned with absolute measures.

In studying, however, the march of thermometer D when the instrument is exposed, or else the sun's rays cut off, we must have recourse to equation (2), and now we can no longer dispense with a knowledge of the value of the constant q. The easiest way of determining it seemed to be to make use in the first instance of the readings in the latter portion of the observation, when thermometer D, after having been heated by exposure, was cooling in consequence of the sun's rays having been intercepted by a screen. In this case $r=0$, and we have simply from (2)

$$u = ce^{-qt} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Hence, if we plot the observations, taking the time for abscissa and the logarithm of the excess u for ordinate, we ought to get a series of points lying in a straight line.

On laying down the observations on paper it was found that, after a slight initial irregularity, the dots representing the observations lay extremely closely in a straight line until the excess u, which began at 49°·7, was reduced to about 3°. They then began to fall a little too high, and the height above the straight line representing the previous observations kept increasing as we proceeded. We have not investigated the cause of this variation, but it seems possible that it may have been due to a slight lagging of the case thermometers. As these were still rising, though D was falling, the lagging would make the temperature of the case appear a little too low, and therefore the excess u a little too great, and therefore the actual reduction of u would be somewhat less

than the calculated. The difference between the real and apparent temperature of the case would be too small sensibly to affect the result until the absolute excess u became comparatively small. We are not, however, concerned with such small excesses u in the actual use of the instrument. The lagging time deduced came out 5·6 minutes.

The reciprocal of this was then introduced into equation (2), which was then applied to the reduction of the first portion of the observation, that portion, namely, which was concerned with the rise of D consequent on exposure. As θ and T are observed and q deemed to be known, the equation contains only two unknown quantities, namely, r, which depends on the radiation, and the arbitrary constant c. These might be determined by any two not unfavourably selected observations of the series, and then the observed and calculated values of u ought to agree for the rest. This, however, was found to be by no means the case, and the differences between theory and observation were far too methodical to be attributable to errors of observation. Equation (2) was then tried as a mere formula of interpolation, q being taken as a disposable constant as well as r and c. Any three observations would of course theoretically suffice for the determination of the three constants, and then the formula would give the calculated final excess, to which r is theoretically proportional, or the calculated value of u for any other observation of the series.

The numerical calculation is much facilitated by choosing for the determination of the constants three observations equidistant in time. If t_0 be the time of the first of the three and Δt the chosen interval, we have from (2)

$$u_0 = \frac{r}{q} + ce^{-qt} \; ;$$
$$\Delta u_0 = -ce^{-qt_0}(1-e^{-q\Delta t}) \; ;$$
$$\Delta^2 u_0 = ce^{-qt_0}(1-e^{-q\Delta t})^2.$$

These equations give

$$1-e^{-q\Delta t} = -\frac{\Delta^2 u_0}{\Delta u_0},$$

which determines q, and then

$$\frac{r}{q} = u_0 - \frac{(\Delta u_0)^2}{\Delta^2 u_0},$$

which gives the calculated final excess.

A rough calculation showed that four minutes was a very suitable interval Δt to choose, which also agreed with the result of actual trials. When various trios were taken from different parts of the series not too near the end, as there the differences became small, and consequently errors of observation would be telling, the calculated final excesses came out remarkably accordant. It thus appeared that equation (2) was no mere formula of interpolation, but that it was very well satisfied, provided, at least, the higher part of the series were not included. The limit to which the excess tended when it had become nearly stationary was evidently a little, though only a little, lower than the calculated limit. This is not to be wondered at, because in the calculation it was assumed that the cooling followed Newton's law, which it is known is not sufficiently accurate when the excess of temperature is as great as 40° or 50°, the cooling in such a case being more rapid than if Newton's law had been followed exactly, the constant involved in it being determined by observations taken with more moderate excesses of temperature.

The values of q as determined by different trios did not come out so closely accordant as the calculated final excesses, as might indeed have been expected from the nature of the equations. Still they agreed in showing that to satisfy the insolation observations the coefficient of cooling q must be taken distinctly larger, in the ratio of about 5 to 4, than when the thermometer cooled after exposure. When a beam of the rays of the sun falls on the front face of the thermometer a portion of heat is absorbed directly by the mercury under the place where the rays strike. As mercury is opaque the portion thus warmed would in the first instance form a thin stratum adjacent to the surface by which the rays entered. Of course currents of convection would arise in the mercury, and also the fluid metal would conduct the heat. But if the heat thus tends to get diffused, on the other hand there is a constant renewal of the superficial heating. Now this specially heated stratum, however thin, helps to raise the mean temperature of the surface, but contributes comparatively little to the mean temperature of the mass; in fact, if it were infinitely thin it would contribute infinitely little. Now the rate of cooling is determined by the average temperature of the surface taken all round, whereas the indication of the thermometer is determined by the average temperature of the whole mass of mercury. Hence the mean temperature of the surface is greater than the mean temperature of the mass; and therefore, if the rate of cooling is supposed to be determined by the temperature indicated by the thermometer, in other words, to be what it would have been if there had been no such inequality of temperature in different parts of the mass, we must to make up for it take a larger coefficient of cooling.

Hitherto a single series only of observations has been mentioned. In fact, a considerable number of series were taken, but as the general mode of treatment and the general character of the results are pretty nearly the same throughout, it does not seem necessary to mention them except when they were made for the special elucidation of particular points.

In the first series the diaphragm used with the lens was the larger one, of $\sqrt{2}$-inch diameter. It seemed desirable to compare the results obtained with this and with the smaller diaphragm of 1-inch diameter. Accordingly, on a day when the sky was clear, series were taken with the two diaphragms in succession. On reducing the results it was found that the effect of radiation through the larger diaphragm was as nearly as possible double that through the smaller.

The object of the quartz plate was to prevent possible irregularities arising from the action of wind, which, it was thought, might cause some interchange between the air inside and outside the cube. It seemed desirable to try the instrument with and without the quartz plate. Comparative series were accordingly taken on a clear and not windy day with and without the quartz plate. The effect was in round numbers about 10 per cent. less with plate on than with plate off. When the plate is used there is loss by reflection from the two surfaces, besides which there may also conceivably be loss by absorption. The loss by reflection can easily be calculated by Fresnel's formula for the intensity of reflected light. If we disregard the double refraction, and take μ for the refractive index answering to the mean of the heat rays incident, and take account of the rays reflected an even number of times, as well as of those which are not reflected at all, we have for the intensity of the

transmitted light, that of the incident being 1—

$$\frac{2\mu}{\mu^2+1}.$$

On multiplying the calculated final excess got from the observations without any plate by the above factor, it came, within the limits of errors of observation, the same as the calculated final excess obtained from the observations with the quartz plate on. It follows that there is no sensible loss due to absorption in the quartz plate. It is to be remembered that the rays that fell upon the quartz had already passed through the glass lens, and also that in the radiation from the sun it is a comparatively small proportion of heat rays that are absorbed by glass and similar substances.

It remains to be explained in what way we were led to the conclusion that the employment of green instead of colourless glass for the bulb of the insolation thermometer must have made but little difference in the results obtained.

Imagine a thermometer to be suddenly exposed to solar radiation, as in Stewart's second actinometer, and consider what its behaviour ought to be on the two extreme suppositions: (1) that the mercury in contact with the glass reflects perfectly all the rays that fall upon it, but that the shell is partially opaque; (2) that the mercury reflects only partially, but that the shell is perfectly diathermanous.

On the first supposition the mercury would not be warmed at all by the rays which fell upon it, but only by conduction from the shell, which itself would be heated by absorption of a portion of the rays that fell upon it, either as they came from the sun or as they were on their way back after reflection at the surface of the mercury. The rise of temperature of the shell would ultimately vary as the time elapsed. But if the shell were at a given temperature the total heat received by the mercury from the shell would vary ultimately as the time during which it has been passing in. But as the temperature of the shell is not constant, but its rise varies ultimately as the time since exposure, the total heat received by the mercury will vary ultimately as the integral of a quantity which varies as the time, and will therefore vary ultimately as the square of the time.

On the second supposition the mercury receives its heat directly from the sun, and the total heat received varies ultimately as the time during which it has been receiving it.

Now in the actual observation the gain of heat was found to be ultimately sensibly proportional to the time elapsed, not to the square of the time, as may be inferred from the fact that the rate of increase was decreasing from the first. We may conclude therefore that the gain of heat was due almost entirely to the imperfection of the reflection from the mercury, which entails direct absorption by the mercury of the portion which failed to be reflected, and only in a comparatively insignificant degree due to absorption of heat by the shell in the passage of the heat through it. We may therefore infer that the substitution of green for colourless glass in the shell of the bulb would make but little difference in the results obtained. This agrees with the experience of Captain Abney, who was led by his experiments on the diathermancy of various kinds of glass to suppose that a thermometer with a bulb of green glass would rise decidedly higher in sunshine than one with a shell

of colourless glass, but found on trial that the substitution of green for colourless glass made only a slight difference.

That the rise should be due chiefly to absorption of radiant heat by the mercury is not to be wondered at. We do not know whether actual experiments have been made on the reflecting power of mercury in contact with glass, but we should probably not be far wrong in estimating it at about 65 per cent., which is about the reflecting power of speculum metal in air. This would leave as much as 35 per cent. of the incident rays to be absorbed by the mercury.

In some of the experiments the change of temperature of the case was barely slow enough to allow of regarding T as constant in the integration of (1). But it is easy to prove that if T vary slowly, though not infinitely slowly, in order to correct for the finiteness of the rate of change, we have merely to add the term $-d\mathrm{T}/qdt$ to the right-hand member of (2).

Report on Constants and Units. *By* C. E. Guillaume.

[A Communication ordered by the General Committee to be printed *in extenso* amongst the Reports.]

The report which I have the honour of presenting to the British Association does not constitute a coherent whole, but has, on the contrary, the character of detached notes, which notes can, however, be classified in three groups. *In the first* I will give the value of several constants determined in modern times. *The second* embraces various propositions which seem to me already in a sufficiently advanced state for it to be possible to come to a decision with regard to them. Lastly, *in the third part* I have made brief allusion to various units which will doubtless come under discussion in a few years, and about which it may be convenient meantime to endeavour to form an opinion.

First Part.—Values of Certain Constants.

Up to quite recent modern times a certain number of geodetic data were derived from the ancient toise of Peru, or from the toise of Bessel. Many physical constants are given in terms of a yard, foot, inch, or mil (·001 inch); it is therefore important to know the value of these various units in terms of the metre, which tends to become more and more, thanks in part to the British Association, the international scientific unit. I ought to say first that, since the Conference of Weights and Measures held in Paris in 1889, the metre and kilogramme are no longer defined by the standards of the Archives of France, but by the copies of these standards which are deposited in the International Bureau of Weights and Measures: these copies are the common property of the nations who adhered to the convention of the metre.

Toises.—According to a determination of M. Benoît, Director of the International Bureau of Weights and Measures, the true value of the ancient toise of France is

$$1^{m}{\cdot}949090,$$

and that of the toise of Bessel is

$$1^{m}{\cdot}949061.$$

Yard.—The accepted value of the metre, according to Kater, is

39·3708 inches;

or, according to Clarke,

39·3704 inches.

These numbers were deduced from standards of the metric system whose value was insufficiently known. But, thanks to modern determinations, we have been enabled to obtain an accurate reduction of these ancient values, as well as those of Mr. Comstock; M. Tittmann has thus found

$1^m = 39{\cdot}3698$ inches.

According to other measurements by Clarke we should have

$1^m = 39{\cdot}3699$ inches.

If we adopt this last value, which seems at present the most probable one, we have

1 yard = 0·914404 metre.
1 foot = 0·304801 ,,
1 inch = 0·025400 ,,
1 metre = 1·093608 yard.
1 ,, = 3 280825 feet.

Electric Standards.—A great number of researches have been devoted to the measurement of the variation of the specific resistance of mercury with temperature; the divergences of these results induced me to undertake the redetermination, and to spare no pains to obtain an accurate result.

I would not trespass on your patience by describing the precautions I have taken, the difficulties encountered in the work, and the reasons which make me feel that this result is sufficiently free from systematic errors. By sixty-four series of measurements made between 0° and 61°, I have arrived at the following mean result:—

1. Apparent resistance of mercury in hard glass, in terms of the hydrogen thermometer:

$$r_T = r_0(1 + 0{\cdot}0008809T + 0{\cdot}000000999T^2).$$

2. True resistance of mercury (corrected for dilatation of the glass) in terms of the same scale:

$$\rho_T = \rho_0(1 + 0{\cdot}0008881T + 0{\cdot}000001010T^2).$$

Second Part.—Propositions.

Introduction.

I wish first to demonstrate by some examples the three following principles:—

1. There would be danger, from the point of view of precision, in suppressing intermediary units which are theoretically unjustifiable, but which can be represented by precise standards.

2. In certain cases it would be advantageous to reduce the constants to the C.G.S. system more than has been done.

3. For ordinary physics and industrial application certain approximate definitions are clearly sufficient, while metrologists can, for their own use, apply the necessary corrections to their results.

1. In theory one unit of each kind is enough to express all quantities of the same nature, but in practice it is useful to keep several units.

The unit of energy in all its forms is the *erg*, or one of its decimal multiples, and if we knew with sufficient exactness an *official* value of the mechanical equivalent of heat we could express in ergs all the constants which calorimetry requires. This will, without doubt, be done in the future, but for the present the final result would lose in precision if we did not keep an intermediate unit, the calorie, of which everyone can easily procure for himself an exact standard; for the reduction to the erg would introduce in certain cases a greater uncertainty than the crude result. In theory we should have gained somewhat, but the result would have been rendered more vague.

2. Let us take, on the contrary, the case of the mechanical equivalent of heat in which several intermediate constants occur more or less, according as it is expressed in normal or in local kilogrammetres or in joules. The most exact mode of realising a given amount of *work* is by absorbing the effect produced by the earth on a heavy body. Then, knowing the mass of a body, it will be necessary, in order to measure the work which it does in falling, to know the value of 'g' at the place of observation and the pressure of the air which are well determined. The whole reduction of the experiment will not introduce an error of 1 : 10,000 in the result, an error which is in this case quite negligible.

Hence, if there is any practical interest in keeping the value of the equivalent in gramme-force centimetre, the question of precision does not come in at all, and unification cannot but gain by completing the reduction to the C.G.S. system.

3. After having theoretically defined a unit it is useful to give a legal value and a standard of it; this legal value carries a special name, and by an odd reversal of the problem, in the progress of measurements, the theoretical unit becomes expressed in terms of the legal standard. If one is afraid that this unnatural state of things might cause inconvenience it is only necessary to consider the case of the metric system to convince oneself that this is not so at all. Originally the kilogramme was defined in terms of the decimetre, taking the density of water as equal to 1. To-day the litre is deduced from the kilogramme, but the litre is no longer rigorously equal to a cubic decimetre.

A certain number of physical constants determined by hydrostatic weighings or by volumetric measures are expressed in terms of the (millilitre)^3 or (millilitre)^3, and not in terms of the centimetre or cm^2.

The occasions in which it would be necessary to establish a difference between these quantities are so rare that I do not believe I am going beyond the truth in saying that the half of physicists have never expressed this difficulty.

With these preliminaries I pass to the propositions.

Unit of Pressure.

So far the unit of pressure has escaped reform, but by a very happy chance we could, by a change of little importance, adopt a unit of pressure which would be in harmony with the C.G.S. system, and whose value would be as convenient and exact a one as possible.

Let us admit provisionally that the *absolute* density of water at 4° is equal to unity; we shall have for the density of mercury at 0° the

number 13·5956, which expresses its *relative* density (specific gravity). The pressure being given by the equation

$$p = hgd,$$

we must choose for g some normal value. Now, there can be no hesitation on this point Meteorologists, metrologists, and geodesists have adopted the normal value at 45°, and at sea-level; physicists have begun to adopt this unity, and any exceptional cases can only be attributed to preconceived ideas. The normal value of g is

$$980{\cdot}65 \frac{\text{cm}}{\text{sec}^2}.$$

Hence $$p\left[\frac{\text{grm} \cdot \text{cm}}{\text{sec}^2 \cdot \text{cm}^2}\right] = h \times 980{\cdot}65 \times 13{\cdot}5956 \left[\frac{\text{cm}}{\text{sec}^2} \cdot \frac{\text{grm}}{\text{cm}^3}\right].$$

Let $p = 10^6$; then $h = 75{\cdot}005$ cm.

Starting from this result *I propose to adopt as the unit of pressure the pressure exerted by a column of mercury* of 75 cm. at 0° under the normal conditions of gravity, and to call this unit the *barie*. This decision would in no wise prevent one from keeping as secondary units the pressures exercised by columns of mercury 1 mm., 1 cm., or 1 m. in height, which bear a simple ratio to the unit pressure.[1]

I do not think that any measurements have been made in which it would be of use to take into account the compressibility for a pressure of one barie; but as this correction varies as the square of the height, the limit beyond which it is no longer negligible is 2 or 3 metres of mercury, a correction must be applied in certain experiments on this account.

The Temperature Scale.

The thermometric system is an entirely arbitrary one, and is subject to only one condition, namely, that of offering a simple relation with precise experimental data. The adoption of a normal unit of pressure in nowise renders it necessary to make use of this unit for the determination of the higher fixed point of the system of temperatures. The adoption of a thermometric system (that is to say of a fundamental interval and of its subdivision) by all physicists alike would evidently be extremely useful, and it is doubtless to avoid breaking suddenly with popular customs that the Centigrade system has not yet come into universal use.

Altogether different is the question of a thermometric scale, that is to say of a function of some natural phenomenon which represents the temperature when it is made to satisfy two equations of condition. Carnot's principle, as Lord Kelvin has shown, allows us to define a scale of temperatures independently of the thermal properties of any given body. The most accurate experiments may lead to the belief that, within the limits of temperature measured as yet, the hydrogen thermometer furnishes us with a scale of temperatures which is practically equivalent to the thermodynamic scale; and it is for this reason that this standard scale has been adopted by the Comité International des Poids et Mesures. I would propose, therefore, that all physicists should be recommended to reduce all exact measurements to the Centigrade scale

[1] For the unit of pressure to be completely defined it is necessary to state whether account shall be taken of the compressibility of mercury and of its vapour pressure, of which the value at 0° is as yet not very well determined.

of the hydrogen thermometer, to which the name of normal thermometric scale should be given.[1]

THIRD PART.

Certain proposals still awaiting their final form and considerations on certain points:—

The Calorie.

It has been proposed on various occasions not to adopt an independent unit of heat-energy. In the equation

$$aMc\theta = j$$

we have—

M = unit of mass of water;
c = specific heat of water;
θ = the interval of temperature corresponding to one degree;
j = either the C.G.S. unit or the practical unit of energy;
a = the heat-equivalent of this energy.

The proposal in question is equivalent to putting $a = 1$, and, as we cannot modify M, to fixing c and θ so as to satisfy the equation.

Messrs. Preece and Forbes proposed in 1889 to modify the temperature system, while Prof. Ostwald prefers to attribute to water a specific heat differing from unity (equal to 4·2, when M = 1 gramme, $\theta = 1°$ C., and $j = 1$ joule). I am also of opinion that it would be best to agree to this last alternative finally; but I have pointed out previously why I think it preferable for the moment to adhere to the *status quo*, and to consider this reform one of those to be accomplished in a more or less distant future. For the present it is, above all things, necessary to define the calorie—that is to say, the temperature at which the specific heat of water shall be considered equal to unity—but I do not think this decision can be taken before the question has again been submitted to a very accurate experimental investigation. The temperature measurements would, of course, be necessarily referred to the normal scale.

Radiation.

No special unit has hitherto been employed for radiation in general, and the only unit which has been used in a particular case is irrational; for in solar radiation all authors have taken for their unit the *calorie per minute*, a unit which conforms to no system at all. No radiation has hitherto been measured to an approximation equal to that with which we know the mechanical equivalent of the calorie, hence there would be no inconvenience in using the watt as the unit of intensity of radiation. This unit would yield very acceptable numbers for the majority of cases of total radiation which we have to measure. We might even push our analysis still further, and divide the spectrum of an incandescent body into bands 0·1 μ (μ=micron) in breadth; the unit would then be the watt in each of these bands. The spectrum would thus be completely defined, and moreover the sums of the partial intensities would be numerically equal to the total intensity of the radiation.

[1] The differences between the indications of various kinds of mercury thermometer and the hydrogen thermometer have been determined by very accurate experiments. The comparisons carried out by M. P. Chappuis with mercury thermometers of hard French glass are the most complete ones that have hitherto been made. We also possess reduction tables for thermometers made of hard Jena glass, of French lead glass, English lead glass, &c. It is much to be desired that only samples of hard glass should be used in the construction of thermometers.

On the Application of Interference Methods to Spectroscopic Measurements. *By* ALBERT A. MICHELSON.

PLATES I.–IV.

[Ordered by the General Committee to be printed *in extenso* among the Reports.]

THE theoretical investigation of the relation between the distribution of light in a source, as a function of the wave-length, and the resulting 'visibility curve' has been given in a paper bearing the same title as the present one in the 'Philosophical Magazine' for April 1891.

The physical definition of 'visibility' there adopted is

$$V = \frac{I_1 - I_2}{I_1 + I_2},$$

in which I_1 is the intensity at the centre of a bright interference band, and I_2 the intensity at the centre of the adjoining dark band. In order to interpret the actual curves obtained by observation of interference fringes, it is first necessary to reduce the results of the eye-estimates of visibility, which may be designated by V_e, to their absolute values as above defined.

For this purpose two quartz lenses, one concave and the other convex, and of equal curvatures, were mounted with their crystalline axes at right angles to each other between two nicols. Under these conditions a series of concentric interference rings appeared. If α be the angle between the principal section of the polariser and the axis of the first quartz, and ω the angle between the axis and the analyser, the intensity of the light transmitted will be

$$I = \cos^2(\omega - \alpha) - \sin 2\alpha \sin 2\omega \sin^2 \pi \frac{\kappa(t_1 - t_2)}{\lambda},$$

where t_1 is the thickness through the first quartz, and t_2 that through the second. If the analyser and polariser are parallel, $\omega = \alpha$, and

$$I = 1 - \sin^2 2\alpha \sin^2 \pi \frac{\kappa(t_1 - t_2)}{\lambda};$$

whence

$$I_1 = 1, \text{ and } I_2 = 1 - \sin^2 2\alpha,$$

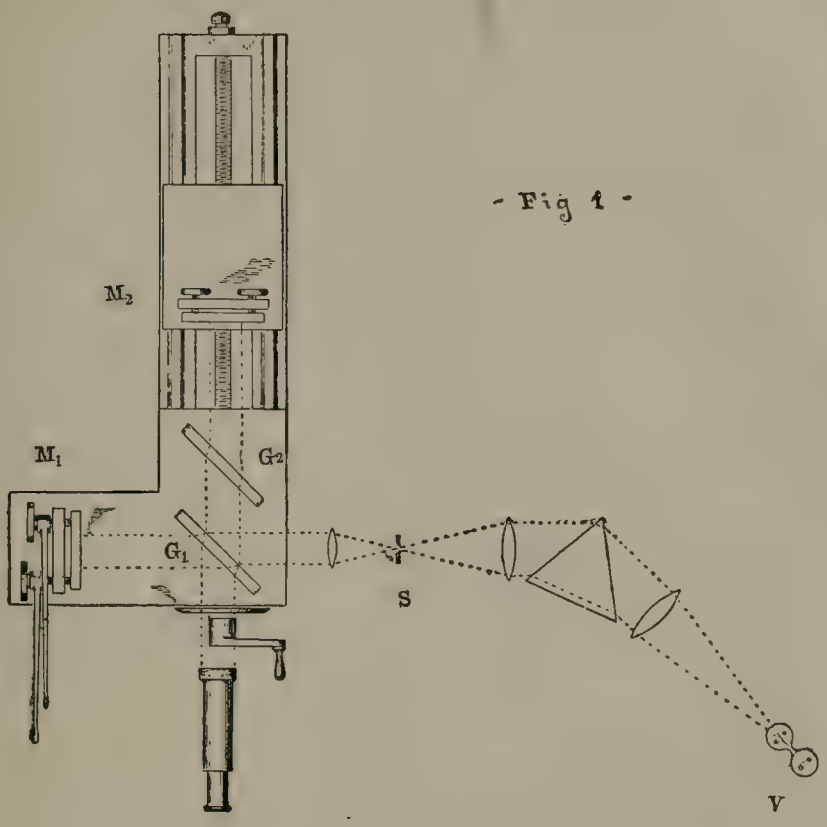
and

$$V = \frac{I_1 - I_2}{I_1 + I_2} = \frac{1 - \cos^2 2\alpha}{1 + \cos^2 2\alpha}.$$

This curve, together with the mean of a number of eye-estimates, given in fig. 2 on opposite page. From these the following table of corrections may be obtained :—

V_e	Cor.	V_e	Cor.
·00	·00	·55	−·12
·05	+·03	·60	−·14
·10	+·04	·65	−·15
·15	+·03	·70	−·16
·20	+·02	·75	−·16
·25	·00	·80	−·14
·30	−·03	·85	−·13
·35	−·05	·90	−·11
·40	−·07	·95	−·08
·45	−·08	1·00	·00
·50	−·10		

- Fig 1 -



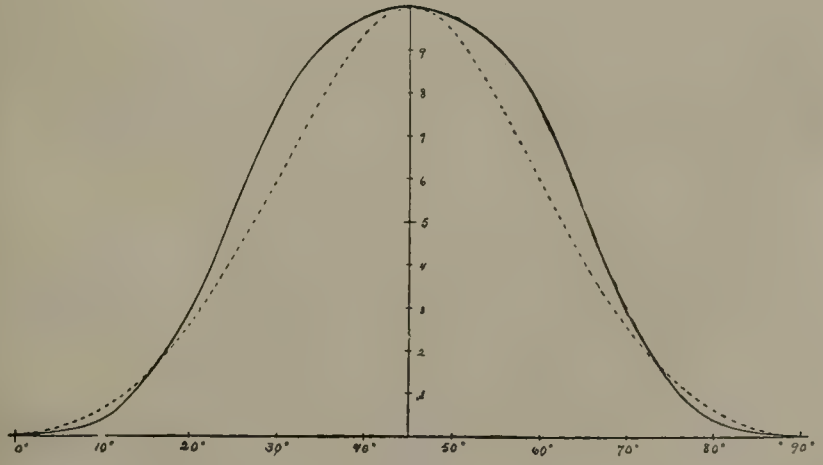


Fig 2 -

Equation Dot'd Curve -

$$V = \frac{1 - \cos^2 2\alpha}{1 + \cos^2 2\alpha}$$

Full Curve -
Eye Estimates - V_e -

The curves show a general tendency to estimate the visibility too high when the interference bands are clear, and too low when they are indistinct. This tendency may be modified by a number of circumstances; thus it increases with the refrangibility of the light used; it is greater when the field contains a large number of bands than when there are but few; it is greater while the visibility curve is falling than when it is rising; it does not seem to be greatly affected by the intensity of the light; finally it varies on different occasions and with different observers. Notwithstanding these disturbing causes, the result, after applying the correction, will rarely be in error by more than one-tenth of its value, and ordinarily the approximation is much closer than this.[1]

The observations necessary to construct the visibility curves, from which the distribution of light in any approximately homogeneous source is to be deduced, may be made with any form of interference apparatus, which allows a considerable alteration in the difference of path between the two interfering streams of light.

The apparatus actually employed for this purpose was designed for the comparison of wave-lengths, and while admirably adapted for the observation of visibility curves it contains many parts not necessary for

[1] The formula for visibility deduced in the preceding paper is

$$V^2 = \frac{C^2 + S^2}{P^2},$$

in which

$$C = \int \phi(x) \cos kx dx,$$

$$S = \int \phi(x) \sin kx dx,$$

$$P = \int \phi(x)\, dx,$$

$$k = 2\pi D,$$

D = Difference in path,

and $\phi(x)$ represents the distribution of light in the source.

In this expression no account was taken of the effect of extraneous light, and it was assumed that the two interfering pencils were of equal intensities. It can be shown that the error due to both these causes tends to lower the visibility; but in either case the correct values may be obtained by multiplying by a constant factor.

In the first case let e be the intensity of the extraneous light, and V′ the resulting visibility; then by definition—

$$V' = \frac{(I_1 + e) - (I_2 + e)}{(I_1 + e) + (I_2 + e)} = \frac{I_1 - I_2}{I_1 + I_2 + 2e}; \text{ or if } \frac{2e}{I_1 + I_2} = r, \quad V' = \frac{I_1 - I_2}{(I_1 + I_2)(1 + r)},$$

whence $V = (1 + r) V'$.

In the second case, let ρ be the ratio of intensities of the interfering pencils; then it can readily be shown that the resulting intensity is

$$I = (1 + \rho^2) P + 2\rho (C \cos \vartheta - S \sin \vartheta),$$

and hence the visibility is

$$V'' = \frac{2\rho}{1 + \rho^2} \frac{\sqrt{C^2 + S^2}}{P},$$

whence

$$V = \frac{1 + \rho^2}{2\rho} V''.$$

If the interfering pencils differ by 25 per cent. the factor $\frac{1 + \rho^2}{2\rho}$ differs from unity by about 4 per cent., so that, in most cases, this cause of error may be neglected.

this use. Fig. 1, page 171, presents the plan of an arrangement which, while showing all the essential parts, is much less complicated. Starting from V, a vacuum tube containing the substance whose radiations are to be examined (and which is usually enclosed in a metal box in order that it may be raised to any required temperature), the light is analysed by one or more prisms, forming a spectrum from which any required radiation may be separated from the rest by passing through the slit S.[1]

The light from S is rendered nearly parallel by a collimating lens, and then falls on a transparent film of silver on the surface of the plane parallel plate G_1.[2]

Here it divides, part being transmitted to the fixed plane mirror M_1 and part reflected to the movable mirror M_2. These mirrors return the light to the silvered surface, where the first part is reflected and the second transmitted, so that both pencils coincide on entering the observing telescope.[3]

A little consideration will show that this arrangement is, in all respects, equivalent to a film or plate of air between two plane surfaces. The interference phenomena are therefore the same as for such an air-plate.

The theory of these interference bands has been given in an article entitled Interference Phenomena in a New Form of Refractometer, 'Philosophical Magazine' for April 1882. As is there shown, the projections of the bands are, in general, conic sections, the position of maximum distinctness being given by the formula

$$P=\frac{t_0}{\tan\phi}\tan i\cos^2\theta,$$

in which t_0 is the thickness of the equivalent air-plate, where it is cut by the axis of the telescope, ϕ, the inclination of the two surfaces, θ and i, the components of the angle of incidence parallel and perpendicular respectively to the intersection of the surfaces, and P, the distance of the plane of maximum distinctness from the surfaces. If θ be small, the variations of P with θ may be neglected, and we have then

$$P=\frac{t_0}{\tan\phi}\tan i,$$

or with sufficient accuracy,

$$P=\frac{t_0}{\phi}i.$$

[1] In the case of close groups of lines the image of the source is first thrown on a slit, otherwise the lines at S would overlap.

[2] The light entering the telescope is a maximum when the thickness of the silver film is such that the intensity of the transmitted light is equal to that of the reflected light. The silvering has another important advantage in diminishing the relative intensity of the light reflected from the other surface. Indeed, for this purpose it is advisable to make the film heavier; even so thick that the reflected light is twice as bright as the transmitted. This does not affect the ultimate ratio of intensities of the interfering pencils—for what is lost by transmission on entering the plate G_1 is made up by reflection on leaving it, the effect being simply to diminish somewhat the whole intensity. Another advantage of the thicker film is that it can be made uniform with far less difficulty than the thin film. It may be mentioned that with this form of instrument the interference fringes in white light present a purity and gorgeousness of coloration that are surpassed only by the colours of the polariscope.

[3] The second plane parallel plate G_2 is made of the same thickness as the first, and is required to equalise the optical paths of the two pencils.

From this it will be seen that the focal plane varies very rapidly with i, so that, unless $\phi=0$, it is impossible to see all parts of the interference bands in focus with equal distinctness. If, however, $\phi=0$, that is, if the two surfaces are strictly parallel, then $P=\infty$, and if the observing telescope is focussed for parallel rays, all parts of the bands are equally distinct. Under these circumstances the interference fringes are concentric circles, whose angular diameter is given by

$$\cos\vartheta=\frac{\Delta}{2t_0}.$$

If for Δ we put $2t_0-n\lambda$, and for $\cos\vartheta$ its approximate value $1-\frac{\vartheta^2}{2}$, we have

$$\vartheta_n=\sqrt{\frac{n\lambda}{t_0}}.$$

In order to obtain an idea of the order of accuracy required in this adjustment, suppose the angle ϑ to be so small that its influence on the distinctness may be neglected. The intensity at the focus of the observing telescope will be

$$I=\iint\cos^2\tfrac{1}{2}\kappa\Delta\,dx\,dy, \text{ where } k=\frac{2\pi}{\lambda}.$$

If the aperture be a rectangle, whose height is $2b$ and width $2a$,

$$I=2b\int_{-a}^{+a}\cos^2\tfrac{1}{2}\kappa\Delta\,dx.$$

But

$$\Delta=2\,(t_0+\phi\,x),$$

whence

$$I=2b\left[a+\cos 2\kappa t_0\,\frac{\sin 2\kappa\phi a}{2\kappa\phi}\right].$$

The maximum value of I is

$$2b\left[a+\frac{\sin 2\kappa\phi a}{2\kappa\phi}\right],$$

and the minimum value is

$$2b\left[a-\frac{\sin 2\kappa\phi a}{2\kappa\phi}\right],$$

whence

$$V=\frac{\sin 2\kappa\phi a}{2\kappa\phi a}.$$

In attempting to verify this formula, by actual observation, one is met by the difficulty that all parts of the bands are not in focus at the same time, the right and left bands being more distinct than the central one, to which attention ought to be directed. Notwithstanding the rather rough character of the observations, the results agree fairly well with theory. If ϕ_0 is the ratio of the wave-length to the width of the rectangular aperture, the above formula becomes

$$V=\frac{\sin 2\pi\phi/\phi_0}{2\pi\phi/\phi_0},$$

from which the second column in the following table was calculated.

ϕ/ϕ_0	V (calc.)	V (obs.)
0·0	1·00	1·00
·1	·94	·94
·2	·75	·73
·3	·50	·40
·4	·24	·13
·5	·00	·09
·6	·15	·10
·7	·22	·09
·8	·19	·07
·9	·15	·05
1·0	·00	·04

From this table it appears that if the visibility is to be estimated by observations with a telescope of 12 mm. aperture (or with a circular aperture about one-fourth greater) an error in the adjustment of the surfaces of a second of arc would produce a diminution of 4 or 5 per cent. in the visibility. Accordingly, if the ways on which the mirror carriage moves are not true to this degree, it is necessary to make the adjustment for every observation.

This can be done with very great accuracy by moving the beam of light from side to side and adjusting the mirror until there is no perceptible alteration in the size of the rings. Since the admissible error in adjustment is inversely proportional to the aperture, the observations may be facilitated by making this as small as possible if there be light to spare. This is all the more necessary for the same reasons, if the surfaces be not true. However, the error due to this source may be easily corrected (since all the observations are affected alike) by multiplying by a constant factor.

In order that the visibility curve may extend as far as possible, it is necessary that the vapour should be very rare. Accordingly, in all but a few cases to be mentioned later, the substance to be investigated was inclosed in a vacuum tube which was previously heated to drive off any moisture or occluded gases.

The vapour was rendered luminous by the discharge from the secondary of a large induction coil, whose primary current was interrupted by a rotary break attached to the armature of an electric motor, making about twenty to thirty breaks per second. The steadiness of the light thus obtained was far greater than with the ordinary Foucault interrupter. Probably it would have been still more satisfactory to use an alternating dynamo properly wound to give a strong current with comparatively few alternations.

The box surrounding the vacuum tube was heated just sufficiently to give a steady bright light, and the temperature then kept as nearly uniform as possible. This temperature was usually taken to represent that of the vapour within the tube. This is, of course, only a rough approximation to the truth; and in some cases the estimate was much too low.

As it was not intended to include in the present work an elaborate study of the effect of temperature, this matter was not of great consequence. It may be suggested, however, that a very much closer approximation to the real temperature could be obtained by winding a platinum wire about the capillary portion of the tube and deducing the temperature from the variation of its resistance. A preliminary experiment in which a platinum wire passing through the tube and heated by a current

until the platinum spiral outside the tube was raised to fixed temperatures would give a means of deducing from the indications of the spiral the true temperature within the tube.

These adjustments being effected, the screw of the 'wave-comparer' was turned to zero; that is, till there was no difference of path between the interfering pencils. At this point the visibility should be as great as possible, and was accordingly marked 100. The screw (of 1 mm. pitch) was then turned through one turn, thus giving a difference of path of 2 mm., and the visibility again estimated, and so on. The curve was then drawn, giving the estimated visibility for each 2 mm. difference of path, and this was corrected for the personal equation as before described.

Hydrogen.[1]

The full curve in fig. 3*b*, Plate I., represents such a curve for the red hydrogen line at a pressure of about 1 mm. and a temperature of about 50° C.

The dotted curve represents

$$V=2^{-X^2/19^2}\cos\cdot 7/30.^2$$

It follows that the visibility curve is practically the same as that due to a double source, whose components have the intensity ratio 7 : 10, and in each of which the light is distributed according to the exponential law, expressed by the first term.

The formula for a double source, where the components are similar, is

$$V^2=\frac{1+r^2+2r\cos 2\pi\dfrac{X}{D}}{1+r^2+2r}\,V^2,$$

in which D, the period of the curve, is inversely proportional to the distance between the components.

But $D=N\lambda_1=(N+1)\lambda_2$, whence

$$\alpha=\lambda_1-\lambda_2=\frac{\lambda^2}{D}.$$

Hence, in the present instance, we have for the distance between the components of the red hydrogen line

$$\tfrac{1}{30}\times(6\cdot56\times10^{-4})^2=1\cdot4\times10^{-8}\text{ mm.},$$

or 0·14 division of Rowland's scale.

Again, if δ be the 'half-width' of the spectral line (the value of x when $\phi(x)=\frac{1}{2}$), then

$$\phi(x)=2^{-\frac{x^2}{\delta^2}},\text{ and }V=e^{-\frac{\pi^2X^2\delta^2}{l^2}}.$$

[1] The hydrogen was prepared by dropping distilled water upon sodium amalgam, and allowing the gas to pass through sulphuric acid into the vacuum tube, which was repeatedly exhausted until the spectrum of hydrogen was nearly pure.

[2] As frequent use is to be made of the function

$$\sqrt{\frac{1+r^2+2r\cos 2\pi\dfrac{X}{D}}{1+r^2+2r}},$$

it will be abbreviated to the form $\cos r/D$.

Fig 6 Na_γ

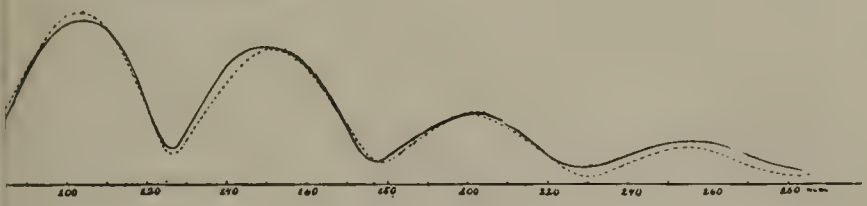
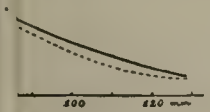


Fig 7 Na_β



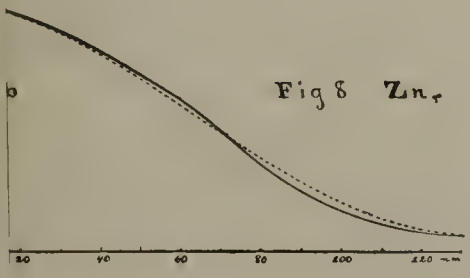
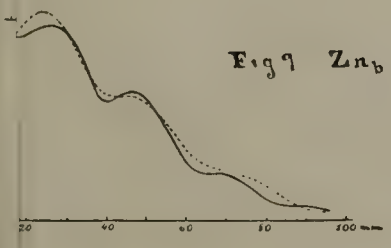
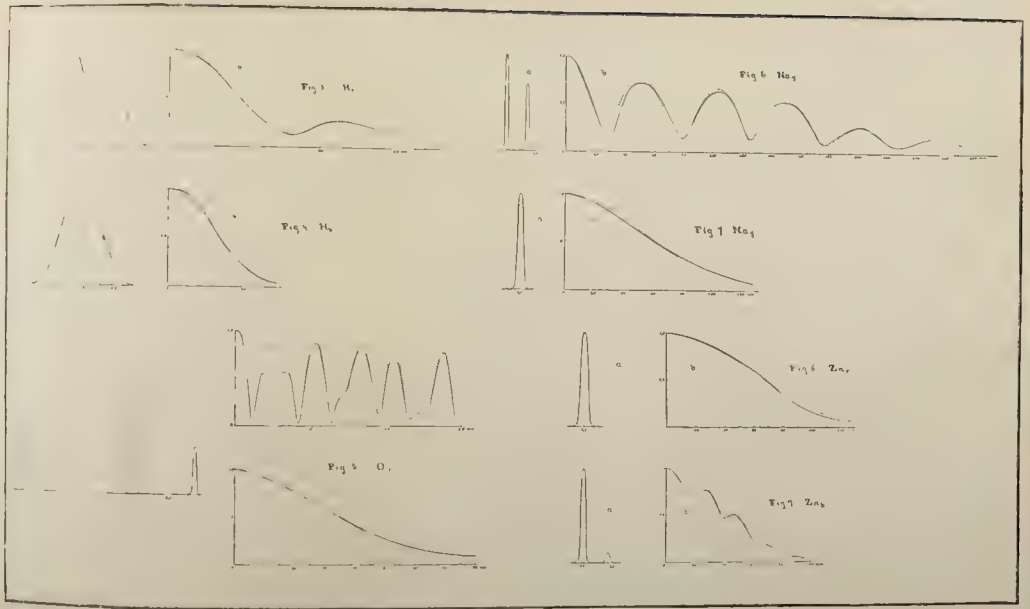


Fig 8 Zn_ϵ

Fig 9 Zn_δ





Illustrating Mr. A. A. Michelson's Paper on the Application of Interference Methods to Spectroscopic Measurements.

If Δ be the value of X for $V=\frac{1}{2}$, then $\delta=\frac{l^2}{\pi}\frac{1}{\Delta}$, or, with sufficient accuracy, $\delta=\frac{\cdot 22}{\Delta}$.

Substituting the value of δ in the equation for V, we have $V=2^{-\frac{X^2}{\Delta^2}}$. The value of Δ in the hydrogen curve is 19. Accordingly, after reducing to the same units as above, we have $\delta=0\cdot049$.

From these data fig. 3*a* was constructed, the full curve showing the distribution of light in the source.

Fig. 4*b*, Plate I., gives, in the full curve, the corrected values of the visibility of the blue hydrogen line, at the same temperature and pressure as before. The dotted curve represents a double exponential, as before. The formula for this curve is

$$V=2^{-X^2/24^2}\cos\cdot 7/28,$$

thus giving $a=0\cdot08$ for the distance between the components, and $\delta=0\cdot057$ for the 'half-width' of each. These values give for the distribution of light in the blue hydrogen line the full curve in fig. 4*a*.

Oxygen.

Fig. 5, Plate I., represents the results obtained from oxygen prepared by heating a tube containing mercuric oxide, drying the gas by sulphuric acid, and exhausting and filling repeatedly, till the spectrum was nearly pure. The lines are much less bright than those of hydrogen, and in order to obtain satisfactory results, the current had to be increased so far that the tube was frequently broken. Notwithstanding the somewhat uncertain character of the observations, it will be seen from fig. 5*a* that the curve for the orange-red line corresponds very well with that given by the formula

$$V=2^{-X^2/34^2}[\cdot36+\cdot32\cos 2\pi X/2\cdot69+\cdot16\cos 2\pi X/4\cdot85 +\cdot16\cos 2\pi X/1\cdot73]^{\frac{1}{2}}.$$

The agreement between the coefficient $2^{-X^2/34^2}$ and the general curve drawn through the maxima is also shown in fig. 5*b*.

The interpretation of these results is that the orange-red oxygen line is a triple, whose components have intensities in the ratios 1 : 1 : 1/2, and whose distances apart are 1·51 and 0·84 respectively, and whose 'half-width' is 0·027. This is shown in fig. 5*c*.

Sodium.

The results obtained from metallic sodium in the vacuum tube are so varied, the character of the lines being so considerably altered by temperature and pressure, that a complete study is at present impossible.

This is especially true of the yellow lines, and the difficulty is considerably increased on account of the insufficiency of the dispersion used, which does not permit the separate examination of the lines. Some reference to the changes mentioned will be given at the close of this

paper. At present it will suffice to take a particular case, the pressure being very low and the temperature about 250°.[1]

The full curve in fig. 6*b*, Plate I., gives the experimental result for the visibility at the maxima for yellow sodium light, corrected for the personal equation. The dotted curve corresponds to the formula

$$V=2^{-X^2/156} \cos \cdot 7/50 \cos \cdot 1/140.$$

The complete equation, assuming that the two lines are alike, is

$$V=2^{-X^2/156^2} \cos \cdot 8/0{\cdot}58 \cos \cdot 7/50 \cos \cdot 1/140.$$

The interpretation of these results is that each of the sodium lines is a close double, as shown in fig. 6*a*.

The yellow-green sodium-line at $\lambda=5687$ is a double whose components are about the same distance apart as the yellow pair. It was found to be far less variable than the yellow; and the full visibility curve, neglecting slight irregularities, gives the experimental results corrected for personal equation. Fig. 7*b*, Plate I., shows that its components are single, and correspond in distribution of light fairly well with the exponential curve, fig. 7*a*.

The same may be said of the orange-red double at 6156 also, except that this seems to have a companion of feeble intensity.

The doubles at 5150 and at 4982 were also examined, the curves showing nearly the same results as the red.

Zinc.

The temperature at which the radiations from metallic zinc could be conveniently observed was in the neighbourhood of the melting-point of the glass of which the vacuum tubes were made. But few observations were recorded, though these were quite consistent. The results of the observations, corrected for personal equation, are given in figs. 8 and 9, Plate I. The former is the record obtained from the red line near 6360, and shows that this line is single, the distribution of light agreeing very well with a simple exponential curve, the 'half-width' being 0·013. The latter shows the results of observation on the blue line near 4811. The dotted curve is the visibility curve due to a distribution represented in fig. 9*a*.

Cadmium.

Metallic cadmium in the vacuum tube at a temperature of about 280° gives a number of very bright lines, widely separated, and varying very slightly with temperature or pressure. Fig. 10*b*, Plate II., shows the experimental visibility curve of the red line near 6439, corrected for the personal equation, together with the simple exponential curve $V=2^{-X^2/138^2}$. The remarkably close agreement leaves no doubt that the distribution of light in the source follows very nearly the exponential law, giving the curve in fig. 10*a*, in which the 'half-width' of the source is 0·0065.

The result of a single set of observations on the green line at 5086 is given in fig. 11*b*, Plate II., the approximate agreement between the full line and the dotted curve (which corresponds to the equation

[1] The curve given above was obtained a year ago; and since then it has been impossible to reproduce it exactly.

Fig 14 Hg_α

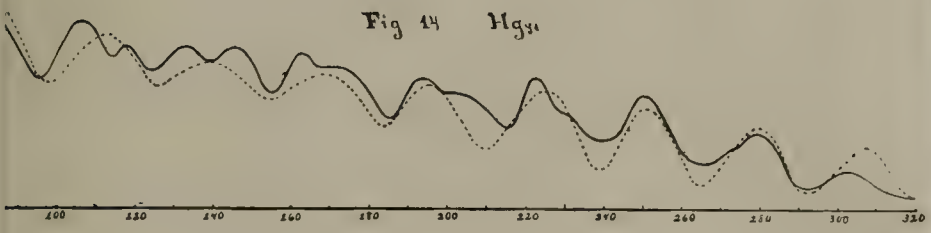
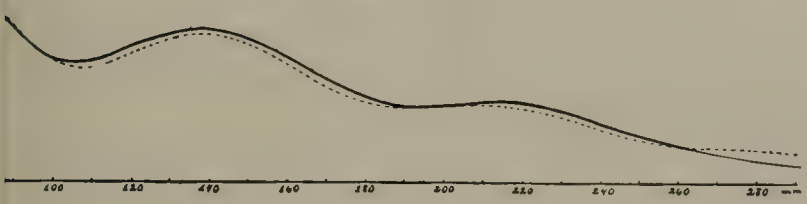


Fig 15 Hg_β



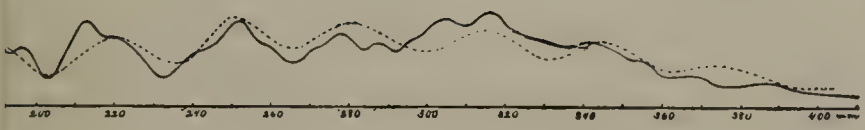
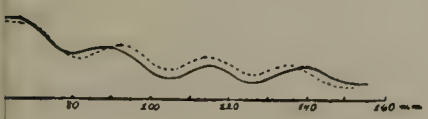
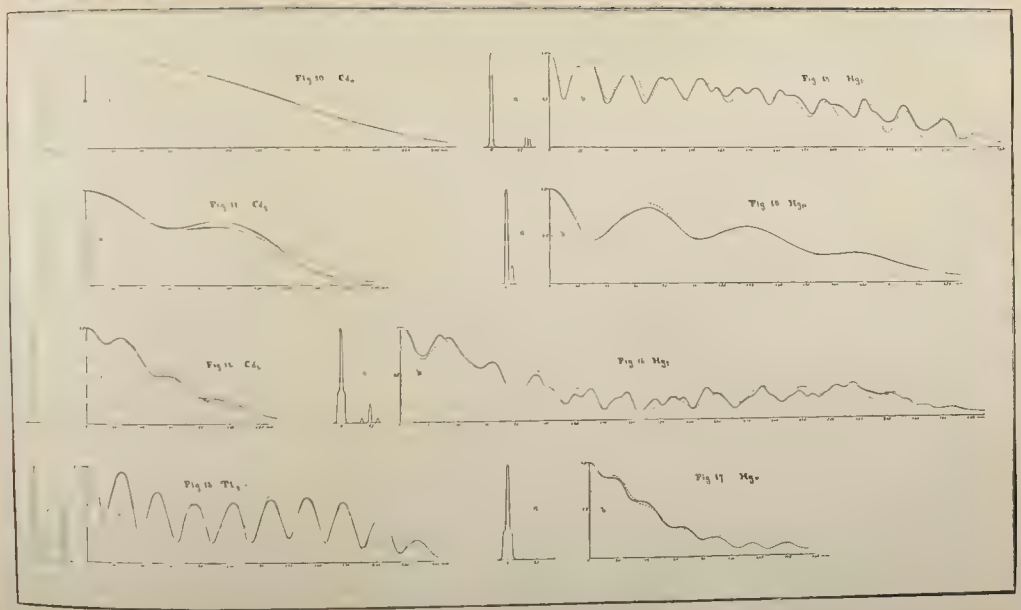


Fig 17 Hg_γ





Illustrating Mr. A. A. Michelson's Paper on the Application of Interference Methods to Spectroscopic Measurements.

$V=2^{-X^2/120^2}\cos\cdot 2/115$) showing that the source is a close double, the intensity of whose components is in the ratio 5 : 1, and whose distance apart is ·022, the "half-width" of each component being 0·0048.

The curve for the blue radiation at 4800 is given in fig. 12*b*, Plate II., and shows that the results may be approximately represented by $V=2^{-X^2/64^2}\cos\cdot 1/32$, which corresponds to the distribution of intensity given in fig. 12*a*.

Thallium.

The metal is not sufficiently volatile at the temperatures attainable, but the chloride answers admirably, giving a brilliant green light, the visibility curve varying but little with temperature. This curve is given in fig. 13*b*, Plate II., together with the dotted curve representing the equation

$$V=\tfrac{1}{3}\cos\cdot 2/160\sqrt{4V_1^2+V_2^2+4V_1V_2\cos 2\pi X/25\cdot 3},$$

in which

$$V_1=2^{-X^2/246^2},$$

and

$$V_2=2^{-X^2/188^2}.$$

This is the visibility curve due to a double source, each of whose components is a close double, as shown in fig. 13*a*.

Mercury.

Mercury in a vacuum tube gives two yellow lines, 5790 and 5770, a very brilliant green line at 5461, and a violet line at 4358.

The yellow lines are not very bright, and are so close together that it is somewhat difficult with the dispersion employed to prevent the light from overlapping. Notwithstanding these difficulties, the close agreement of a number of observations shows that the curve for the lower line, given in fig. 14*b*, Plate II., is a close approximation to the truth. Neglecting the effect of a line of feeble intensity at a distance of about ·24 from the principal line, the distribution of light in the source is represented in fig. 14*a*, which gives for the visibility curve

$$V=\tfrac{1}{4}\sqrt{3V_1^2+V_2^2+6V_1V_2\cos 2\pi X/28},$$

in which

$$V_1=2^{-X^2/200^2},$$

and

$$V_2=2^{-X^2/260^2}\cos\cdot 5/280.$$

Fig. 15*b*, Plate II., represents the results of observations on the upper yellow line, omitting some peculiarities due to the presence of one or more lines of feeble intensity. The curve agrees closely with the formula

$$V=\tfrac{1}{4}\sqrt{3V_1^2+V_2^2+6V_1V_2\cos 2\pi X/70},$$

in which

$$V_1=2^{-X^2/183^2},$$

and

$$V_2=2^{-X^2/126^2},$$

which represents the visibility curve produced by two lines of intensities, 1 : 3 and separated by 0·019 division as shown in fig. 15*a*.

The green mercury line is one of the most complex yet examined. The constituent lines are, nevertheless, so fine that the interference bands are frequently visible when the difference of path is over four-tenths of a metre. The full curve in fig. 16*b*, Plate II., gives the results of observations corrected for personal equation, while the dotted curve represents the equation

$$V=2^{-X^2/230^2}\sqrt{\cdot69V_1^2+\cdot03V_2^2+\cdot28V_1V_2\cos 2\pi X/31\cdot4},$$

in which

$$V_1=\cdot62+\cdot38\cos 2\pi X/360,$$

and

$$V_2=\cdot77+\cdot23\cos 2\pi X/110.$$

This is the visibility curve corresponding to the distribution represented in fig. 16*a*. The components of the line, for simplicity, have been assumed to be symmetrical, as figured; but the observations are not sufficiently accurate to determine whether, for instance, each component is a double or a triple line. In this case, also, as in the preceding ones, it is impossible, from the data given, to determine whether the smaller component is to the right or left of the principal line. A direct observation with the grating showed, however, that the smaller component is towards the red end of the spectrum.

The full curve shows that there is at least one other line—probably more than one—whose intensity is roughly one-twentieth of the principal line, and whose distance from it is about three times that of the chief components.

The violet mercury line is much more difficult to observe than the others. The results obtained by observation, corrected for personal equations, are given by the full curve fig. 17*b*, Plate II. The formula for the dotted curve is

$$V=\sqrt{\cdot88V_1^2+\cdot12V_1V_2\cos 2\pi X/23},$$

in which

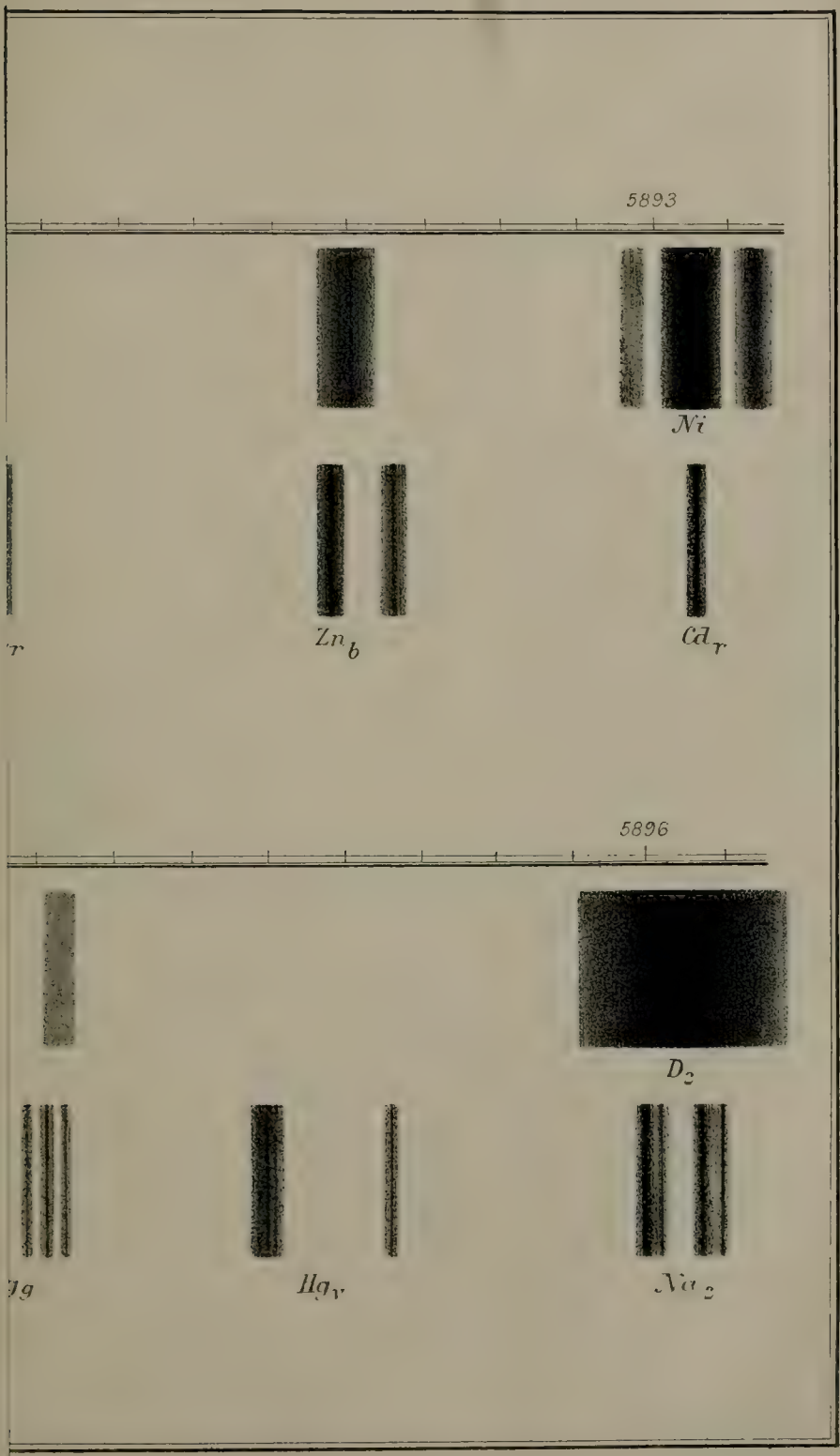
$$V_1=2^{-X^2/74^2}\,[\cdot62+\cdot38\cos 2\pi X/200],$$

and

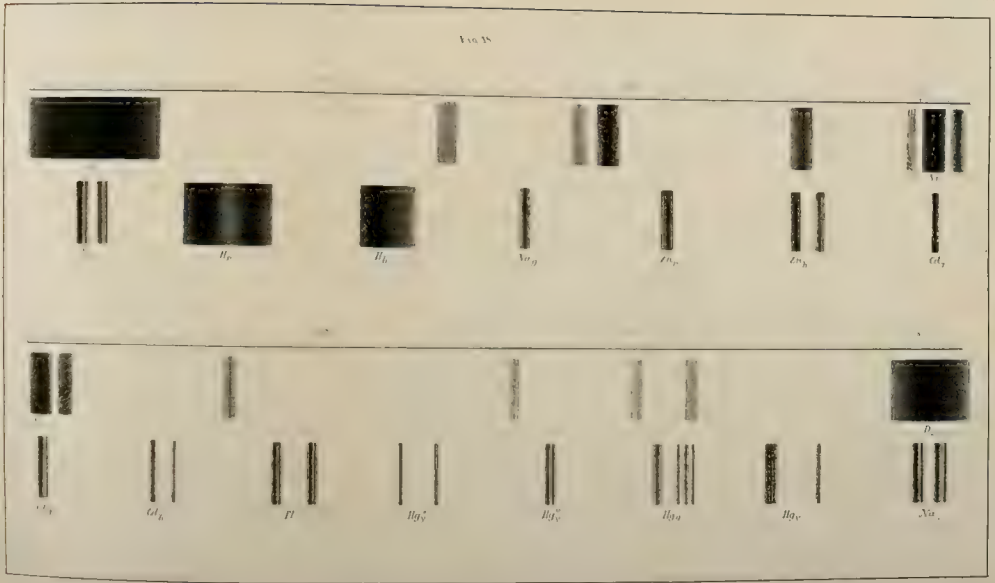
$$V_2=2^{-X^2/120^2},$$

the resulting distribution of light shown in fig. 17*a*.

The results of the preceding work are collected for comparison in fig. 18, Plate III., together with the D group in the solar spectrum. From these, as well as from the curves, it will be seen that it is easy by this method to separate lines whose distance apart is only a thousandth of that between D_1 and D_2, and even to determine the distribution of light in the separate components. The conditions most favourable to high values of the visibility are low density and low temperature, and these conditions were complied with as far as possible. Still, in many cases, the range of visibility due to slight variations of the conditions shows that the behaviour of each substance must be carefully studied under all possible circumstances of temperature, pressure, strength of



scopic Measurements.



Illustrating Mr. A. A. Michelson's Paper on the Application of Interference Methods to Spectroscopic Measurements.

current, size and shape of the electrodes, diameter of the vacuum tube, &c.

The effect of temperature and of pressure on the visibility may be readily accounted for on the kinetic theory. In fact, there is but little doubt that these are the chief, if not the sole, causes of the broadening of the spectral lines, and the consequent diminution of visibility, the latter cause acting by altering the period of the source by frequent collisions, and the former by the alteration in the wave-length of the light due to the motion of the source in the line of sight.

If, now, the density of the vapour is very low, the second cause may be ignored, and it will be shown that in the case of hydrogen this is the case when the pressure is one or two millimetres.

In most of the cases investigated the pressure was so low that the discharge passed with difficulty. Supposing, then, the effect of collisions to be insignificant, let it be proposed to find the effect due to the motion of the molecule in the line of sight. If v be the mean velocity of the molecule and V that of light, then the formula for the resulting visibility curve as given by Lord Rayleigh[1] is $h=(l-a'')/(l+a'')$.

If the definition of visibility as given above be taken, however, this becomes

$$V=a''=\exp\left[-\pi\left(\frac{\pi X}{\lambda}\frac{v}{V}\right)^2\right].$$

If Δ be the difference of path at which the visibility is reduced to half its value at $X=0$, then

$$\Delta=\frac{1}{\pi}\sqrt{\frac{l2}{\pi}}\cdot\frac{V}{v}\lambda,$$

or approximately,

$$\frac{\Delta}{\lambda}=\cdot 15\,\frac{V}{v}.$$

If we take for hydrogen $v=2000$ metres per second, then $\frac{\Delta}{\lambda}=22500$.

Again, if we ignore the difference in the temperature (about which there is considerable uncertainty), at which the other substances were examined, the velocities v would vary inversely as the square root of the atomic weight, and the number of waves in the difference of path at which the visibility is 0·5 is therefore $22500\sqrt{m}$.

Considering the difficulties and uncertainties of the problem, the following table shows a very remarkable agreement between the values actually found and the calculated results.[2]

[1] 'On the Limit to Interference when Light is Radiated from Moving Molecules,' *Phil. Mag.*, April 1889.

[2] It should be stated that the value of Δ for the yellow sodium line, if taken from the curve, would be much larger than that given. This was the mean of a number of observations taken within the past month. As has been stated before, this particular curve has not been obtained since last year. A few other substances, very difficult to examine, either because the lines are too feeble, or because the spectrum is so unstable, have given results not quite so consistent as the above, though all are of the same order of magnitude as that required by theory.

Substance	At. Wt.	λ	Δ	$N=\frac{\Delta}{\lambda}$	N (calc.)
H_r	1	656	19·0	30,000	22,500
H_b	1	486	8·5	18,000	22,500
O	16	616	34·0	55,000	80,000
Na_r	23	616	66·0	107,000	108,000
Na_y	23	589	80·0	133,000	108,000
Na_{gy}	23	567	62·0	109,000	108,000
Na_g'	23	515	44·0	85,000	108,000
Na_g''	23	498	55·0	110,000	108,000
Zn_r	65·5	636	66·0	104,000	182,000
Zn_b	65·5	481	47·0	98,000	182,000
Cd_r	112·0	644	138·0	215,000	238,000
Cd_g	112·0	509	120·0	236,000	238,000
Cd_b	112·0	480	64·0	134,000	238,000
Hg_y'	200·0	579	230·0	400,000	317,000
Hg_y''	200·0	577	154·0	270,000	317,000
Hg_g	200·0	546	230·0	420,000	317,000
Hg_b	200·0	436	100·0	230,000	317,000
Tl	203·6	535	220·0	400,000	322,000

In order to show conclusively that the effect of density may be neglected in the foregoing observations, as well as to ascertain the law governing the broadening of spectral lines by pressure or density, a series of observations was made on the red hydrogen line at varying pressures, with the results shown in fig. 19*a*, Plate IV.[1]

From these curves the following table was calculated :—

Pressure in mm.	δ
90	·128
71	·116
47	·095
23	·071
13	·056
9	·053
3	·050
5	·048

In fig. 19*b* the curved line gives the relation between δ and $\frac{1}{p}$, and shows clearly that when p is less than 5 mm. the effect of collisions has almost entirely ceased. If we take as variables δ and p, the results agree very closely with the straight line $\delta-\delta_0=kp$, in which $\delta_0=\cdot047$ (the 'half-width' of the line at zero pressure in the units adopted), $k=\cdot00093$, and p is the pressure in millimetres.[2]

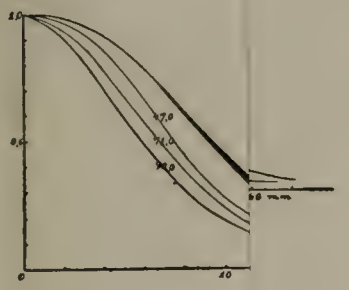
The same results were found for the blue hydrogen line, though, as might be expected, these were not so consistent.

It thus appears that in the case of hydrogen—and probably in all other cases—the width of the spectral line diminishes towards a limit as the pressure diminishes, which depends upon the substance and its temperature; and that the excess of width over this limit is simply proportional to the pressure.

In general, it may be said that under considerable ranges of temperature and pressure the character of the visibility curve remains the

[1] The numbers against the curves denote pressure in millimetres.

[2] In the figure the numbers representing values of the abscissæ for this line should be multiplied by 100.



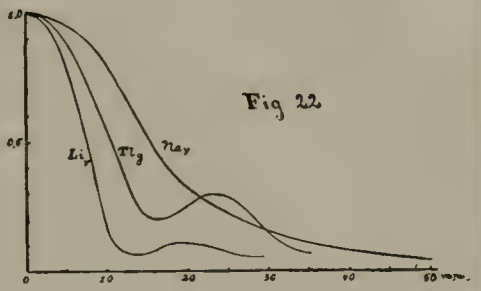
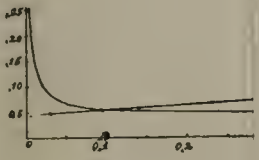
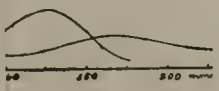
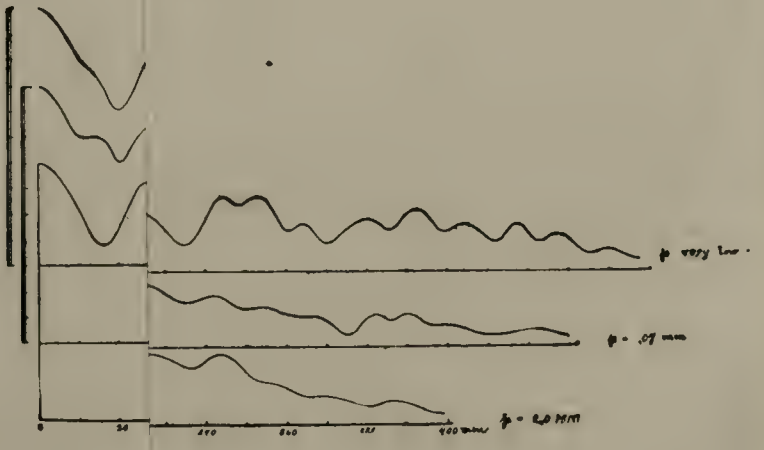


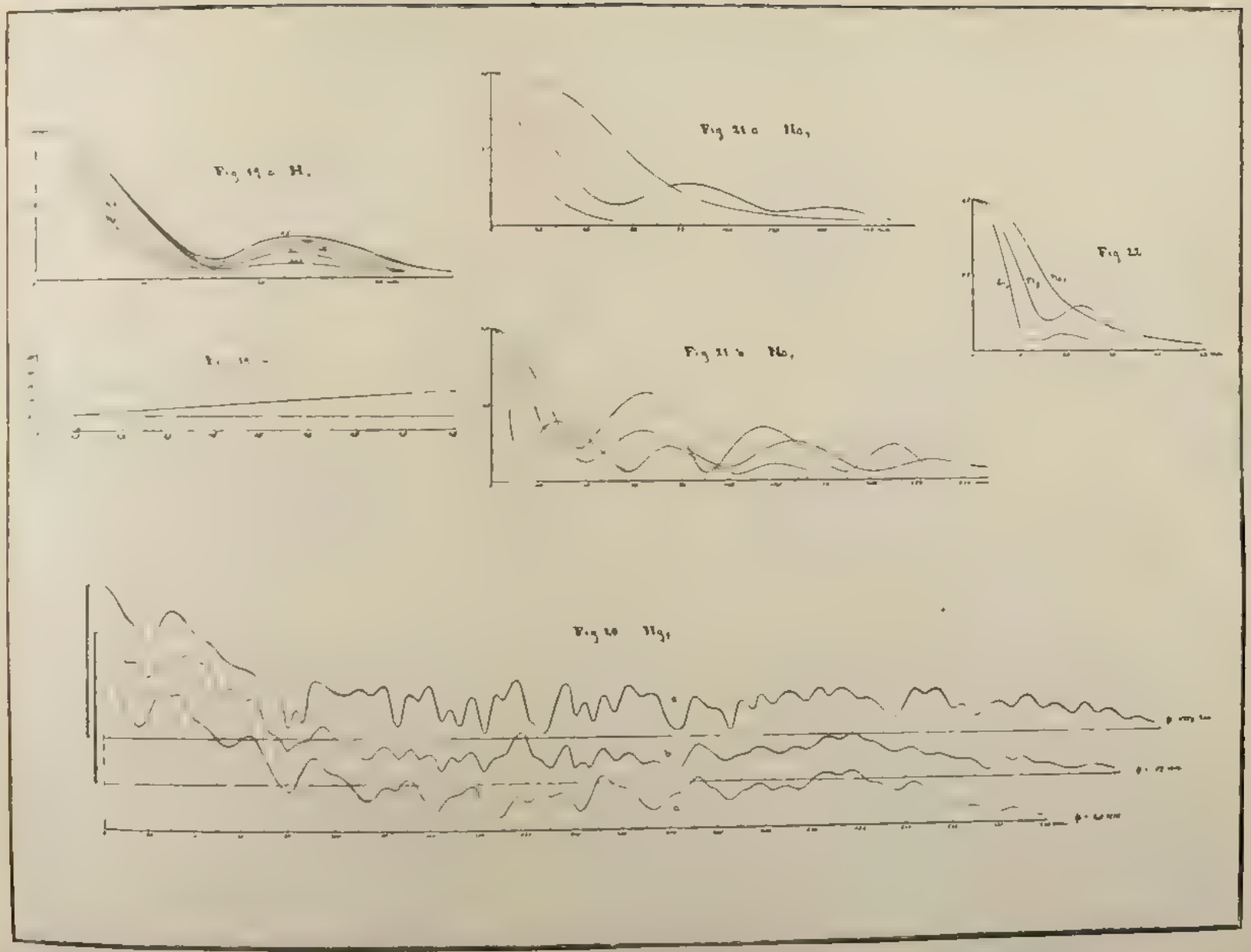
Fig 22.







pectroscopic Measurements.



Illustrating Mr. A. A. Michelson's Paper on the Application of Interference Methods to Spectroscopic Measurements.

same; but it may be important to note that there are a number of exceptions to this rule, among which the green mercury line and the yellow sodium line may be especially mentioned.

Thus, fig. 20*a*, Plate IV., represents the visibility curve usually observed for the green mercury line, and fig. 20*c* represents that obtained when the vacuum is so high that the discharge passes with difficulty, while fig. 20*b* represents the intermediate stage. This last observation was obtained by placing the mercury in an atmosphere of hydrogen whose pressure could be measured by a McLeod gauge.

It might be objected that the presence of a foreign substance might of itself affect the distribution of light in the source, and therefore the form of the curve. In order to test this point, a series of observations of the red hydrogen line was taken, while the tube contained liquid mercury, which was heated until the mercury spectrum was at least ten times as bright as that of the hydrogen. The character of the visibility curve was not perceptibly altered.

In the same series of experiments it was found that, provided the pressure of the hydrogen remained constant, the effect of a change in temperature from 75° to 140° had no appreciable effect on the result. In this connection it may be mentioned that the character of the curve for the green mercury line was not essentially altered when, in place of metallic mercury, the nitrate, iodide, or the chloride was substituted, the only important effect being a diminution in the visibility in the order named.

In the case of yellow sodium light it has already been mentioned that the character of the curve is more variable than that of any other line thus far examined. This is illustrated by the curves in fig. 21*a* and fig. 21*b*, Plate IV. It has not been possible thus far to devote the attention which a systematic investigation demands. These changes are very puzzling to trace, but undoubtedly much of the difficulty is due to the fact that the dispersion employed was not sufficient to permit the separate examination of the components. Still, there can be no doubt that the width of the lines, their distances apart, and their relative intensities vary rapidly with changes in temperature and pressure.

In addition to the preceding investigations of visibility curves for light emanating from a rare gas or vapour in a vacuum tube the curves for sodium, thallium, and lithium, in the flame of a Bunsen burner, have been observed, and the results are given in fig. 22, Plate IV. The thallium and lithium lines are clearly double, the distance between the components of the former agreeing very well with the results obtained with the vacuum tube.

These substances were brought into the flame in the ordinary way, and the results obtained were at least as good as when a finely divided solution was used according to the method of Gouy. It appears from these curves that the width of the line is about ten times as great as when the vacuum tube is used. But if the temperature of the flame be taken at 1500° C., and that in the vacuum tubes at 350° C., the lines should be only twice as broad in the former case as in the latter. It appears, then, that notwithstanding the small quantity of substance present (barely enough to colour the flame) the real density must be comparable to that of the vapour of the substance boiling under atmospheric pressure.

The principal object of the foregoing work is to illustrate the advan-

tages which may be expected from a study of the variations of clearness of interference fringes with increase in difference of path. The fundamental principle by which the 'structure' of a line or group of lines is determined by this method is not essentially different from that of spectrum analysis by the grating, both depending, in fact, on interference phenomena, but in consequence of the almost complete freedom from errors arising from defects in optical or mechanical parts, the method has extraordinary advantages for this special work. A glance at fig. 18, Plate III., will give a fair idea of the 'resolving power' of the method as compared with that of the grating. In order that the comparison be quite fair, however, it would be necessary to take for a comparison spectrum that of the substances here used, and under the same conditions. With the best instrumental appliances now in use, it is difficult to 'resolve' lines as close together as the components of either of the yellow sodium lines. It is evident, however, that by *Light-wave Analysis*, if I may venture so to call the foregoing method, a tenth of this distance is obviously within the limit; indeed, if the width of the lines themselves be less than their distance apart, there can be no limit.

Supplement.

I. It has already been pointed out that in many cases it is difficult or impossible to decide between two or more distributions of lines which give very nearly the same visibility curve; and when there are many lines in the source, the combinations of intensities and arrangements of these from which a type may be selected are enormously great. Indeed, even when the number of lines is greater than three, excepting perhaps the cases where the lines may be in pairs (as in the case of yellow sodium light), the resulting visibility curve becomes so complex that it is very difficult to analyse. Doubtless in many cases where the components are not too close, the grating will give the information necessary for the investigator to select the proper combination.

It may readily be shown that the formula

$$V^2=\frac{C^2+S^2}{P^2},$$

for the *visibility* curve due to a distribution of light, $y=\phi(x)$, is identical with that of the *intensity* curve at the focus of a telescope provided with apertures which produce this distribution in the light passing through. Accordingly, if a telescope be provided with apertures adjustable in width, or length, and distance apart, the diffraction image of a distant illuminated slit will give, at once, a representation of the whole visibility curve, and by adjustment of intensities and distances any particular visibility curve may be more or less accurately copied, thus furnishing a means of studying the relations between V and $\phi(x)$, which, while giving, perhaps only a rough approximation to the truth, may prove more convenient than analytical or graphical methods.

II. One of the purposes which led to these investigations was the search for a radiation of sufficient homogeneity to serve as an ultimate standard of length. It will appear from the curves of cadmium that there are three lines which may be used for this purpose. The red cadmium line is almost ideally homogeneous, and will readily permit the estimation of

a change of phase in the interference fringes of one-hundredth of a fringe in a total distance of 200 millimetres, or over 300,000 waves.

Both the green and the blue lines are fairly well adapted for the purpose, and will prove very valuable as checks. Each of these, however, has a small companion, and it is necessary to know the effect of this in altering the phase of the interference bands.

If ϕ be the fraction of a wave by which the position of a minimum is shifted on account of the presence of the companion, α the number of 'periods' in the difference of path, and r the ratio of the intensities, then

$$\tan 2\pi\phi = -\frac{r \sin 2\pi\alpha}{1 + r \cos 2\pi\alpha}.$$ [1]

Thus, if $r=1/4$, ϕ is a maximum when α is about $1/3$, and for this we have, approximately,

$$\phi = -\cdot 04.$$

This is the largest correction to be applied, and is negative if the brighter line has the greater wave-length. It is theoretically possible by this means to determine, in case of an unequal double or a line unsymmetrically broadened, whether the brighter side is toward the blue or the red end of the spectrum.

III. It has been argued that, even if all practical difficulties in making large gratings could be removed, nothing further could be gained in resolution of groups of spectral lines on account of the real width of the lines themselves, caused by the lack of homogeneity in the radiations which produce them. The results of the preceding investigations show that, while this is very far from being true with present gratings, such a limit undoubtedly exists. The accordance between the measured widths of eighteen lines shows further that this broadening of lines in a rare gas can be fully accounted for by the application of Doppler's principle to the motion of the vibrating atoms in the line of sight, and, indeed, furnishes what may be considered one of the most direct proofs of the kinetic theory of gases.

The form of the ultimate components of all the groups of lines thus far examined is found to agree fairly well with an exponential curve, $\phi(x)=e^{-a^2x^2}$, which shows that the distribution of velocities cannot vary widely from that demanded by Maxwell's theory.

If the limit abovementioned were due solely to the motion of the molecule, and the radiating substance could be rendered luminous while its temperature was very low, it might be possible to observe interference phenomena with a difference of path of many metres. But it must be considered that, since every vibrating molecule is communicating its energy to the ether in the form of light waves, its vibrations must diminish in amplitude; consequently the train of waves is no longer homogeneous, even though the vibrations remain absolutely isochronous, and the result is a broadening of the line and limitation of the difference of path at which interference is visible.

[1] See *Phil. Mag.*, April 1891, p. 345. (The value of r is the reciprocal of that here used.)

Fourth Report of the Committee, consisting of Professor W. C. Roberts-Austen (*Chairman*), Sir F. Abel, Mr. E. Riley, *and* Mr. J. Spiller, Professor J. W. Langley, Mr. G. J. Snelus, Professor Tilden, *and* Mr. Thomas Turner (*Secretary*), *appointed to consider the best method of establishing an International Standard for the Analysis of Iron and Steel.* (*Drawn up by the Secretary.*)

In the previous report of this committee it was mentioned that four out of the five proposed international standards had been prepared and distributed as previously arranged, and that the work of the British analysts was practically completed. During the past year a meeting of the British analysts has been held, and the analytical results have been discussed. It was found that the agreement among these numbers was good, more particularly so in view of the relatively small quantity of material which could be supplied to each analyst, and it was decided to publish an account of the work of the British chemists so far as the investigation has proceeded. This intention was communicated to Professor Langley, as representing the American Committee, and received his cordial approval. The results now communicated have therefore to do only with the work of the British analysts and with the standards Nos. 1, 2, 3, and 4.

It will be remembered that the analysts entrusted with the investigation in this country were as follows :—

Mr. A. H. Allen . . .	Sheffield,
„ W. Jenkins . . .	Dowlais,
„ G. S. Packer . . .	Glasgow,
„ J. Pattinson . . .	Newcastle-on-Tyne,
„ E. Riley . . .	London,
„ J. E. Stead . . .	Middlesbrough,

and the Royal School of Mines, London.

Complete reports have been received from Messrs. Jenkins, Packer, Pattinson, Riley, and Stead, while Mr. Allen, who was prevented by other engagements from completely analysing the samples sent to him, has forwarded a report on the determination of sulphur in iron and steel.

Unfortunately, the analyst attached to the Royal School of Mines has suffered from a long and serious illness, and his results have not been completed. It has therefore been decided to dispense with his report, and for the present the Royal School of Mines is represented by the work of Mr. E. Riley, whose reputation as an analyst is so well known and recognised.

The report received from Mr. W. Jenkins gave the following values as the results of his analyses :—

—	C	Si	S	P	Mn
Standard No. 1 . .	1·43	·260	·010	·02	·26
„ „ 2 . .	·82	·200	·008	·02	·14
„ „ 3 . .	·55	·144	·015	·02	·13
„ „ 4 . .	·165	·008	·040	·08	·13

These results agree very fairly well with those of the other analysts, with the exception of the carbon in Standard 3, which is 0·09 per cent. higher than any of the other analysts returned. Unfortunately, Mr. Jenkins, after a prolonged period of ill-health, died in May last, and hence no check determination has been performed in this case. The Committee desire to record their regret at the loss of an analyst who was so courteous, so skilful, and so much respected. No account has been received of the methods used by Mr. Jenkins, except references in a letter to the Secretary, which indicate that the silicon was determined by the sulphuric acid method, and checked by the use of nitric and sulphuric acids—the sulphur by an evolution process, and the manganese by an acetate separation and precipitation by bromine. The phosphorus was weighed as phospho-molybdate.

The results obtained by Mr. Packer were as follows :—

—	C	Si	S	P	Mn
Standard No. 1 . .	1·44	·28	traces	·017	·267
,, ,, 2 . .	·85	·194	traces	·012	·144
,, ,, 3 . .	·46	·14	traces	·022	·130
,, ,, 4 . .	·146	·008	·036	·08	·130

The methods employed by Mr. Packer were as follows :—

Carbon.—1. Ordinary colour test on 0·1 gram of steel.

2. Separation of carbonaceous matter by ammonio-chloride of copper and subsequent oxidation of the carbon by means of sulphuric and chromic acids ; collecting and weighing the CO_2 in potash bulbs in the usual manner.

Silicon.—Oxidation of the steel by nitric acid, evaporation to dryness, and ignition ; redissolving in hydrochloric acid, filtering, and weighing the insoluble silica. The purity of the silica was tested by evaporating with hydrofluoric acid ; any residue was weighed and suitable allowance made.

Sulphur.—The steel was dissolved in hydrochloric acid, and the evolved gases passed into a solution of copper sulphate ; the precipitated sulphide was filtered and weighed after ignition as oxide or sulphide (or mixed oxide and sulphide) of copper.

Phosphorus.—The filtrate from the determination of silicon was evaporated to a small bulk and transferred to a flask, ammonia was then added till a slight permanent precipitate was produced. Ten cubic centimetres of an aqueous 8 per cent. solution of ammonium molybdate was added and nitric acid to decidedly acid reaction. The solution was digested till clear, filtered, the precipitate washed with dilute nitric acid, and finally with water ; it was then washed on to a weighed watch glass, dried, and weighed.

Manganese.—The steel was dissolved in nitric acid with the addition of hydrochloric acid, and the iron precipitated by addition of acetate of ammonia and boiling. The manganese was precipitated in the filtrate by addition of bromine and ammonia and weighed after ignition as Mn_3O_4.

The report of Mr. Pattinson supplied the numbers which follow :—

—	C	Si	S	P	Mn
Standard No. 1 . .	1·393	·271	trace	·019	·263
„ „ 2 . .	·802	·182	·007	·012	·145
„ „ 3 . .	·461	·140	trace	·022	·158
„ „ 4 . .	·142	·009	·040	·075	·130

The following is an outline of the methods adopted by Mr. Pattinson :—

Carbon.—The sample was dissolved in a solution of double chloride of copper and ammonium, filtered through asbestos, and the residue well washed and burnt in oxygen. The double chloride used was proved to be free from carbonaceous matter.

Silicon.—The sample was dissolved in hydrochloric acid, evaporated to dryness, and the residue dissolved in hydrochloric acid and hot water. After filtration and washing, the silica was ignited and weighed ; its purity was tested by treatment with hydrofluoric acid and due allowance made for any residue.

Sulphur.—1. The sample was dissolved in hydrochloric acid and the evolved gases passed into an ammoniacal solution of cadmium chloride. The precipitated cadmium sulphide was dissolved in the beaker by the addition of bromine water and acidification with hydrochloric acid, and the sulphur precipitated as $BaSO_4$.

2. The drillings were dissolved in nitric acid, and the solution evaporated to dryness with addition of hydrochloric acid, redissolved in hydrochloric acid and water, filtered, and the sulphur precipitated as $BaSO_4$.

Manganese.—1. Estimated gravimetrically by the ammonium acetate and bromine process. The precipitate after ignition was weighed as Mn_3O_4, and the impurities carried down with the precipitate were determined, and the necessary correction made.

2. Also estimated volumetrically by the process described by Mr. Pattinson ('Trans. Chem. Soc.,' 1879, p. 365).

Phosphorus.—The sample was dissolved in nitric acid and evaporated to dryness after the addition of hydrochloric acid. The residue was redissolved in hydrochloric acid, filtered, and the filtrate treated with metallic zinc, free from phosphorus, in order to eliminate arsenic and reduce the iron to the ferrous condition. The solution was then boiled, a few drops of ferric chloride added, and the phosphorus precipitated in combination with iron by addition of ammonia and acetate of ammonia. The precipitate was separated by filtration, dissolved in nitric acid, the phosphorus precipitated by ammonium molybdate and weighed as ammonium phospho-molybdate.

The analytical results obtained by Mr. E. Riley are as follows :—

—	C	Si	S	P	Mn
Standard No. 1 . .	1·387	·250	·004	·017	·278
„ „ 2 . .	·811	·192	·007	·012	·140
„ „ 3 . .	·456	·153	traces	·016	·144
„ „ 4 . .	·147	·008	·041	·081	·124

The following is a brief outline of the methods of analysis adopted by Mr. Riley in these determinations :—

Carbon.—By solution of the sample in sodium copper chloride and

combustion of the carbonaceous residue in a stream of oxygen. Cupric chloride was first prepared by roasting copper scale in a muffle, dissolving in pure hydrochloric acid, and passing chlorine into the solution to convert the whole into the cupric condition. To a concentrated solution of the cupric chloride so prepared, 10 per cent. of sodium chloride was added, and the solution so obtained, which is distinctly acid, is employed for dissolving the steel. The separated carbon was collected on an asbestos filter, and burned in a glass tube with pure recently ignited oxide of copper.

Sulphur and Phosphorus.—The steel was oxidised by pure nitric acid (sp. gr. 1·40), redistilled in Mr. Riley's laboratory, evaporated to dryness, heated, dissolved in pure hydrochloric acid (also redistilled in the laboratory), and the silica separated; the excess of hydrochloric acid evaporated off until only just sufficient acid was left to keep the iron in solution. The sulphur was precipitated by barium chloride, allowed to stand twenty-four hours, and weighed as $BaSO_4$. The filtrate from the determination of sulphur was reduced by addition of sulphide of sodium, the precipitated barium sulphate was filtered off, and the phosphorus precipitated as basic perphosphate of iron by boiling with ammonium acetate. If there is not sufficient ferric oxide present, a little bromine is added. The precipitate is dissolved in hydrochloric acid, citric acid is added, then excess of ammonia and a small quantity of 'magnesia mixture.' After standing twenty-four hours the precipitate is filtered off and weighed as $Mg_2P_2O_7$.

Manganese.—The iron was separated as basic ferric acetate, the manganese precipitated by bromine and weighed as Mn_3O_4.

Silicon.—The silica separated in the determination of sulphur and phosphorus was washed, ignited, and weighed; it was afterwards treated with hydrofluoric acid and any residue weighed and deducted.

Mr. Stead reported as follows:—

——	C	Si	S	P	Mn
Sample No. 1 . .	1·419	·252	·007	·016	·229
„ „ 2 . .	·796	·186	·007	·012	·137
„ „ 3 . .	·455	·130	·008	·024	·161
„ 4 . .	·154	·009	·040	·075	·137

Mr. Stead has supplied the following brief outline of the methods he adopted, and which are almost identical with those employed by Mr. Pattinson:—

Carbon.—The sample was dissolved in double chloride of copper and potassium, the carbon separated by filtration through asbestos, and after careful washing burned in a porcelain tube with copper oxide in air or oxygen.

Silicon.—By solution in hydrochloric acid, evaporation to dryness, and strongly heating; redissolving in hydrochloric acid and water, filtering and weighing as SiO_2.

Sulphur.—This was determined both by oxidation with aqua regia and also by the evolution method; no further details were supplied.

Phosphorus was precipitated and weighed as phospho-molybdate of ammonia.

Manganese was estimated by the acetate and bromine gravimetric process, and also by Pattinson's volumetric method.

Mean of the Analytical Results.—If it be assumed that all the results previously given are of equal value, and that the proportion of sulphur returned as 'traces' does not exceed ·005 per cent., the following figures give the composition of Standards 1, 2, 3, and 4 as deduced from the analyses by the five chemists from whom reports have been received:—

——	No. 1	No. 2	No. 3	No. 4
Carbon	1·414	·816	·476	·151
Silicon	·263	·191	·141	·008
Sulphur, not more than .	·006	·007	·008	·039
Phosphorus . . .	·018	·014	·021	·078
Manganese . . .	·259	·141	·145	·130

It is, however, probable that, as a doubtful result is included among the carbon determinations in Standard No. 3, this mean value is about ·02 per cent. too high, and should be about ·456 per cent.

When it is remembered that each analyst employed the methods of analysis which he individually preferred, it must be acknowledged that the agreement in the results is closer than might have been anticipated, as it is well known that certain methods for which one analyst has a marked preference are distrusted by other experimenters. This appears to show that methods which are unsatisfactory, or even incorrect, in the hands of one analyst may, with slight modifications, give excellent results with another operator. In such determinations we have to deal, not only with the inherent accuracy or inaccuracy of the process itself, but also with the manipulative and analytical skill of the operator, derived from long experience in the use of the process he adopts.

The proportion of sulphur present in the Standards Nos. 1, 2, and 3 is very small, being less than 0·01 per cent. It is noticed that in many cases the amount of sulphur present in American pig irons and steels is less than is usually found in British samples, and it would be interesting, if possible, to determine the cause of this difference.

All the samples were tested for chromium, but in no case was the presence of this element detected.

Standard No. 5 has been prepared during the past winter by Mr. J. E. Stead at Middlesbrough, and the Committee desire to acknowledge the importance of the assistance which Mr. Stead has thus rendered. The American and British Committees have already been supplied with their portions of the standard thus prepared, and the remaining portions of the standard will be distributed as soon as possible. It is hoped that the analyses will be completed, so as to allow of a final report at the next meeting of the Association.

The American Committee has nearly completed its work on Standards 1, 2, 3, and 4, and it is proposed to publish the results in a few months. These results have not yet been revised for publication, but on the whole it is believed that a close agreement will be noticed between the work of the British and American Committees.

The German Committee has devoted much attention to the study of methods of analysis in connection with the international standards, but the results are not yet ready for publication. No report has been received at present from the French and Swedish Committees.

Sixth Report of the Committee, consisting of Professor W. A. Tilden *and* Professor H. E. Armstrong (*Secretary*), *appointed for the purpose of investigating Isomeric Naphthalene Derivatives.* (*Drawn up by* Professor Armstrong.)

It was stated in the last report that Mr. Rossiter and the writer had devoted much time to the study of the dibromonaphthalenes, but that the results were not sufficiently complete to render their publication desirable; an account of the work contemplated in this passage was communicated to the Chemical Society late in the year (cf. 'C.S. Proceedings,' 1891, p. 182).

In this communication data were given which suffice to characterise and differentiate *five* of the isomeric dibromonaphthalenes, *i.e.*, the 1 : 4, 1 : 4′, 1 : 3, 1 : 2′, and 1 : 3′ modifications. The action of bromine on α- and β-dibromonaphthalene was also described, and the nature of the complex product formed on *di*-brominating naphthalene, which has occupied the attention of so many observers, was finally determined, it being shown to consist of 1 : 4 dibromonaphthalene (m.p. 82–83°) mixed with the 1 : 4′ isomeride (m.p. 132°).

When naphthalene is dibrominated, 1 : 4 dibromonaphthalene is the major product, so much so that this modification crystallises out in an almost pure state from the solution of the crude product in alcohol. It has been stated by Darmstaedter and Wichelhaus that when naphthalene-α-sulphonic acid is brominated a product is obtained which on crystallisation from alcohol first affords 1 : 4′ dibromonaphthalene, the remainder of the product melting at 68–70°, and resembling that obtained from naphthalene. It therefore seemed probable that, whereas naphthalene yields chiefly 1 : 4 dibromonaphthalene, the α-sulphonic acid yields chiefly the 1 : 4′ derivative, and that consequently the *acid* radicle exercises a marked influence in determining the entrance of bromine into the unsubstituted nucleus (cf. Report for 1886), an influence much greater than that of bromine towards sulphuric acid, as bromonaphthalene yields little but the 1 : 4 acid when sulphonated. Darmstaedter and Wichelhaus' experiments have been repeated by the writer, and the accuracy of this conclusion confirmed; a very considerable amount of 1 : 4′ bromosulphonic acid is formed on brominating naphthalene-sulphonic acid, 1 : 4 dibromonaphthalene being quite a minor product.

On comparing the dibromo-products obtained from naphthalene with the dichloro-products, an unusual divergence is apparent; there can be no doubt, however, that this is attributable to the extreme instability of bromine addition compounds of naphthalene. The dichloronaphthalenes are, in fact, products of the withdrawal of 2HCl from the tetrachloride, while the dibromonaphthalenes are products of the action of bromine on bromonaphthalene, and hence it is that the 1 : 3 modification, which is the chief product of chlorination, is absent from the product of bromination. When the conditions are similar the difference in behaviour of naphthalene towards chlorine and bromine is of the ordinary character, and such as was to be expected; thus when α-chloronaphthalene is chlorinated by means of SO_2Cl_2 at such a temperature (100–180°) as to prevent the persistence of an addition compound, it yields pure 1 : 4 dichloronaphthalene and no trace of the 1 : 3 isomeride, which is the principal pro-

duct of the hydrolysis of naphthalene tetrachloride. β-Chloronaphthalene in like manner yields a mixture of the 1 : 2 and 1 : 2′ derivatives. The results of a series of experiments on the formation of chlorinated naphthalenes at high temperatures by means of SO_2Cl_2 and similar chlorinating agents which the writer and Dr. Wynne are engaged in carrying out will be given on a subsequent occasion; they desire, however, here to recognise the assistance which they have received from Mr. Jenks.

Finally, it may be mentioned that Mr. Rossiter and the writer, having repeated Meldola's experiments on the bromonitronaphthylamines, have been led to interpret this author's results in a manner somewhat different from that originally adopted by him, but in accordance with the results of more modern enquiries (cf. 'C.S. Proceedings,' 1891, p. 186; Meldola, 'C.S. Trans.,' 1892, p. 766).

A comprehensive survey of the very numerous recorded facts shows that the 'laws of substitution' in the naphthalene series are in the main easy to decipher, and pervaded by a few very simple principles. The writer and Dr. Wynne hope during the coming year to discuss these in a comprehensive memoir, dealing with the investigation which they have conjointly carried on now during over six years. It is perhaps not undesirable to state that no single fact has yet been recorded serving to support the view advocated by Claus, that the structure of naphthalene is unsymmetrical. Whatever its exact inner structure may be, the two nuclei of naphthalene must be represented alike.

Fourth Report of Committee, consisting of Professor H. M'LEOD, Mr. W. C. ROBERTS-AUSTEN (*Secretary*), Professor A. W. REINOLD, *and* Mr. H. G. MADAN, *appointed for continuing the Bibliography of Spectroscopy.*

THE collection of titles of spectroscopic papers has been continued during the year, but as Mr. Madan is not now residing in Oxford, he has not been able to verify all the references.

Mr. Nagel has undertaken some portion of the work, and he is proposed as a member of the Committee in place of Professor Reinold, who wishes to retire.

Report of the Committee, consisting of Dr. W. J. RUSSELL, Professor W. N. HARTLEY, Professor W. RAMSAY, Captain W. DE W. ABNEY, *and* Dr. A. RICHARDSON, *appointed for the investigation of the Action of Light on the Hydracids of the Halogens in presence of Oxygen.*

A LARGE amount of work has been done during the past year, but the Committee feel that the results obtained cannot at this stage be profitably laid before the Section. They hope, however, to be able to present a detailed report to the Association at the next meeting.

Report of the Committee, consisting of Sir H. E. Roscoe, Dr. Marshall Watts, Mr. J. N. Lockyer, Professors Dewar, Liveing, Schuster, W. N. Hartley, *and* Wolcott Gibbs, *and* Captain Abney, *on Wave-length Tables of the Spectra of the Elements and Compounds.* (*Drawn up by* Dr. Marshall Watts.)

Lithium.

Kayser and Runge ('Ueber die Spectren der Elemente.' Berlin, 1890).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
6708·2	0·2	10sr	6706·7 Thalén	1·96	4·4	14902·7
6103·77	0·03	10sr	6102·2 „	1·80	4·8	16378·5
4972·11	0·1	6bn	4971·2 „	1·47	5·9	20106·3
4602·37	0·1	10sr	4602·2 „	1·37	6·5	21721·4
4273·44	0·2	4n	4273·3 „	1·28	7·0	23393·3
4132·44	0·2	8nr	4131·7 Liveing & Dewar	1·24	7·2	24191·6
3985·94	0·2	2n	3984·5 „	1·20	7·6	25080·6
3915·2	0·2	6nr	3913·5 „	1·18	7·7	25533·8
3838·3	3·0	1n	3838·? „	1·15	7·8	26045·4
3794·9	5·0	4n	3799·0 „	1·14	7·9	26343·3
3718·9	5·0	2n		1·12	8·1	26881·5
3670·6	5·0	1n		1·11	8·2	27235·3
3232·77	0·03	8sr	3232·0 „	0·99	9·5	30923·7
2741·39	0·03	6sr	2741·0 „	0·85	11·4	36466·4
2562·60	0·03	4sr	2567·5 „	0·80	12·3	39010 6
2475·13	0·1	4sr	2475·0 „	0·78	12·7	40389·2
2425·55	0·1	2sr	2425·5 „	0·77	13·1	41214·7
2394·54	0·2	1sr	2394·5 „	0·76	13·2	41748·5
*(2373·9)			2373·5 „	0·75	13·4	42111·4
*(2359·4)			2359·0 „	0·75	13·5	42370·2

Sodium.

Kayser and Runge ('Ueber die Spectren der Elemente.' Berlin, 1890).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
*(8200·3)			8199 Abney	absent	?	?	12197 ?
*(8188·3)			8187 „	absent			12215 ?
6161·15	0·1	8n	6160·2 Thalén	6161·50 ?	1·81	4·8	16225·9
6154·62		8n	6154·4 „	6154·49 ?	„	„	16242·2
5896·16		10sr	5895·13 „	5896· D.	1·74	5·0	16955·2
5890·19		10sr	5889·12 „	5890·19 „	„	„	16972·4
5688·26	0·15	8n	5687·3 „	5688·42 ?	1·68	5·2	17574·9
5682·90		8n	5681·5 „	5682·58 ?	„	„	17587·4
5675·92	0·15	2n	5674·4 „	5675·90 ?	1·67	„	17613·1
5670·40		2n	5668·0 „	absent	„	„	17630·2

SODIUM—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5153·72	0·1	6n	5155·0 Thalén	5153·60 ?	1·53	5·8	19397·7
5149·19		6n	5152·7 „	5149·29 ?	„	„	19414·7
4983·53	0·2	6n	4983·3 „	4983·71 ?	1·48	5·9	20060·2
4979·30		6n	4982·0 „	4979·41 ?	„	„	20077·2
			4980·5 L. & D.				
4752·19	0·15	4n	4751·4 „	4752·30 ?	1·41	6·2	21036·7
4748·36		4n	4747·5 „	4748·36 ?	„	„	21053·7
4669·4	0·5	4n	4667·5 „	4669·47 ?	1·39	6·4	21409·6
4665·2		4n	4663·7 „	4665·32 ?	„	„	21428·9
4546·03	0·2	2n	4543·6 „	4546·10 ?	1·35	6·5	21990·7
4542·75		2n	4540·7 „	absent	„	„	22004·6
4500·0	1·0	2n	4496·4 „	?	1·34	6·0	22216·2
4494·3		2n	4494·5 „	?	„	„	22244·4
(4423·7)			4423·0 „	?	1·32	6·7	22598·8
(4420·2)			4419·5 „	?	„	„	22616·7
(4393·7)			4393 „	?	1·31	6·8	22753·1
(4390·7)			4390 „	?	„	„	22768·6
(4343·7)			4343 „	?	1·30	6·9	23014·9
(4325·7)			4325 „	?	1·29	„	23110·7
3303·07	0·03	8r	3301·2 Cornu	3303·07	1·01	9·3	30265·6
3302·47		8r	3308·8 „	3302·47	„	„	30271·1
2852·91	0·05	6r	2853·3 L. & D.		0·88	10·9	35041·0
2680·46	0·1	4r	2679·0 „		0·84	11·6	37295·4
2593·98	0·1	2r	2593·3 „		0·81	12·1	38538·7
2543·85	0·1	1r			0·80	12·4	39298·1
2512·23	0·2	1r			0·79	12·5	39792·8

* Lines within brackets not measured by Kayser and Runge.

POTASSIUM.

Kayser and Runge ('Ueber die Spectren der Elemente.' Berlin, 1890).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
7699·3	5·0	10nr	7696·5 Deslandres	absent	2·2	3·7	12984·5
7665·6		10nr	7663·2 „	„	2·2	3·7	13041·5
6938·8	0·5	8	6946 L. de B.*	„	2·03	4·2	14407·5
6911·2	0·5	8	6913 „	„	2·02	4·3	14465·1
5832·23	0·05	4n	5831 „	„	1·72	5·1	17141·0
5812·54		2n	5812 „	„	1·71	5·1	17199·1
5802·01		6n	5802·1 Thalén	„	1·71	5·1	17230·3
5782·67		6n	5782·6 „	„	1·70	5·1	17288·0
5359·88	0·15	4n	5353·6 „	„	1·59	5·5	18651·6
5343·35		2n	5338·6 „	„	1·58	5·6	18709·2
5340·08		4n	5334·5 L. & D.†	„	1·58	5·6	18720·7
5323·55		4n	5322·6 Thalén	„	1·57	5·6	18778·9

POTASSIUM—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5112·68		2n	5112 L. de B.	absent	1·51	5·8	19553·4
5099·64	0·20	2n	5098 L. & D.	?	1·51	5·8	19603·4
5097·75		1n	5095 L. de B.	?	1·51	5·8	19610·7
5084·49		2n	5081 „	?	1·51	5·8	19661·9
4965·5		1n	4963 „		1·47	6·0	20133·0
4956·8	1·0	1n	4956 L. & D.	?	1·47	6·0	20168·3
4952·2		1n	4950		1·47	6·0	20187·0
4943·1		1n	4942		1·47	6·0	20224·2
(4870·8)			4870		1·44	6·1	20526·1
(4863·8)			4863		1·44	6·1	20555·6
(4856·8)			4856		1·44	6·1	20585·3
(4850·8)			4850		1·44	6·1	20610·8
(4808·8)			4808		1·43	6·2	20790·7
(4803·8)			4803		1·43	6·2	20812·4
(4796·8)			4796		1·42	6·2	20842·8
(4788·8)			4788		1·42	6·2	20877·6
(4759·8)			4759		1·41	6·2	21004·8
4047·36	0·03	6r	4045 „	absent	1·21	7·4	24700·1
4044·29		8r	4042 „	„	1·21	7·4	24718·8
3447·49	0·03	6r	3445·0 „	?	1·05	8·8	28997·8
3446·49		8r	3443·6 „	?	1·05	8·8	29006·2
3217·76	0·03	4r	3216·5 „		0·98	9·5	31068·0
3217·27		6r			0·98	9·5	31072·7
3102·37	0·1	2r	3101·0 „		0·95	9·9	32223·5
3102·15		4r			0·95	9·9	32225·8
3034·94	0·1	4r	3033·0 „		0·93	10·1	32939·5
2992·33	0·15	2r	2992·0 „		0·92	10·3	33408·5
2963·36	0·2	1r	2963 4 „		0·91	10·4	33735·8
2942·8	1·0	1r	2942·0 „		0·91	10·5	33970·8

* L. de B. = Lecoq de Boisbaudran. † L. & D. = Liveing and Dewar.

RUBIDIUM.

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. III. 5. Berlin, 1890).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
7950·	5·0	10br	7951·0 L. de B.	absent	2·3	3·6	12575·0
7811·	5·0	10br	7800·0 „	„	2·3	3·8	12799·7
6298·7	0·2	4n	6296·7 Thalén	? 6298·65	1·85	4·6	15871·7
6206·7	0·2	4n	6204·2 „	absent	1·83	4·7	16106·9
6159·8	0·2	1n	6160·2 „	„	1·81	4·8	16229·5
6071·2	0·2	2n	6070·2 „	„	1·79	4·9	16466·3
5724·41	0·15	6n	5724·0 L. de B.	„	1·69	5·2	17464·8
5654·22	0·15	2n	5650·0 „	? 5654·10	1·67	5·2	17680·7
5648·18	0·15	4n		absent	1·67	5·2	17699·6
5431·83	0·15	2n	5429·0 „	„	1·61	5·4	18405·6

RUBIDIUM—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5362·94	0·2	2n	5359·0 L. de B.	? 5362·96	1·59	5·5	18641·0
(5259·8)			5259·0 „		1·56	5·6	19006·5
(5194·8)			5194·0 „		1·54	5·7	19244·3
(5161·8)			5161·0 „		1·53	5·7	19367·4
(5085·8)			5085·0 „		1·51	5·8	19656·8
(5021·8)			5021·0 „		1·49	5·9	19907·3
4215·72	0·03	6r	4216·0 „	absent	1·26	7·1	23713·6
4201·98	0·03	8r	4202·0 „	„	1·26	7·1	23791·2
3591·74	0·05	4r		? 3591·63	1·09	8·5	27833·2
3587·23	0·05	6r		?	1·09	8·5	27868·2
3351·03	0·05	2r		? 3351·03	1·02	9·1	29832·2
3348·86	0·05	4r		? 3348·80	1·02	9·1	29851·8

CÆSIUM.

Kayser and Runge ('Ueber die Spectren der Elemente.' Berlin, 1890).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
6973·9	5·0	6n	6975·0 L. de B.	absent	2·0	4·1	14335·1
6723·6	5·0	8n	6723·0 „	„	1·97	4·3	14868·7
6213·4	0·5	2n	6219·0 „	„	1·83	4·7	16089·5
6010·6	0·3	4n	6007·0 „	„	1·77	4·9	16632·4
5845·1	0·5	4n	5850·0 „	? 5845·2	1·72	5·0	17103·3
5664·0	0·5	6n	5662·0 „	? 5664·25	1·67	5·2	17650·2
5635·1	0·5	4n	5637·0 „	absent	1·66	5·2	17740·7
5579·3	0·5	1n	5572·0 „	„	1·65	5·3	17918·1
(5501·9)			5501·0 „		1·63	5·4	18170·1
5465·8	0·1	2n	5464·0 „	„	1·62	5·4	18290·1
(5410·9)			5410·0 „		1·60	5·5	18475·7
(5345·9)			5345·0 „		1·58	5·6	18700·3
(5310·8)			5310·0 „		1·57	5·6	18824·0
(5257·8)			5257·0 „		1·56	5·6	19013·8
4593·34	0·05	6r	4592·2 Lockyer	? 4593·31	1·37	6·5	21764·2
4555·44	0·05	8r	4554·9 „	absent	1·35	6·5	21945·3
3888·83	0·1	4r			1·17	7·7	25707·0
3876·73	0·1	6r			1·16	7·7	25787·2
3617·08	0·3	2r			1·09	8·4	27638·2
3611·84	0·2	4r			1·09	8·4	27678·3

Magnesium.

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. IV. Berlin, 1891).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5711·56	0·15	2	5710·7 L. & D.	5711·32 ?	1·69	5·2	17503·1
5528·75	0·10	6	5527·4	5528·625 ?	1·63	5·3	18082·0
5183·84	0·03	10r 3†	5183·0	5183·798	1·54	5·7	19285·0
5172·87	0·03	10r 3†	5172·0	5172·867	1·53	5·7	19325·9
5167·55	0·03	8r 3†	5167·0	5167·580	1·53	5·7	19345·8
4730·42	0·25	1n		4730·22 ?	1·40	6·3	21133·5
4703·33	0·05	8n	4703·5	4703·173	1·40	6·3	21255·2
4571·33	0·05	4	4570·5 „	4571·25	1·36	6·5	21869·0
4352·18	0·05	8n	4351·2 „	4352·10	1·30	6·9	22970·1
4167·81	0·10	1n	4166·0 „	4167·40 ?	1·25	7·1	23986·3
4058·45	1·00	2n	4057·3 „	4058·10 ?	1·22	7·4	24632·5
3987·08	1·00	2n		?	1·20	7·6	25073·4
3838·44	0·03	10r 4*	3837·9 H. & A.	3838·43	1·15	7·8	26044·4
3832·46	0·03	10r 4*	3832·1 „	3832·43	1·15	7·8	26085·1
3829·51	0·03	10r 4*	3829·2 „	3829·53	1·15	7·8	26105·2
3336·83	0·03	10n 4†	3336·2 „	3336·83	1·02	9·2	29959·4
3332·28	0·03	8n 4†	3331·8 „	3332·27	1·01	9·2	30000·3
3330·08	0·03	8n 4†	3329·1 „	3330·06	1·01	9·2	30020·1
3097·06	0·03	10r 5*	3096·2 „	3097·02	0·95	9·9	32278·8
3093·14	0·03	8r 5*	3091·9 „	3093·20	0·95	9·9	32319·7
3091·18	0·03	8r 5*	3089·9 „	3091·20	0·95	9·9	32340·2
2942·21	0·03	8n 5†	2942·0 L. & D.		0·91	10·5	33977·6
2938·67	0·03	6n 5†	2938·5 „		0·91	10·5	34018·5
2936·99	0·03	4n 5†	2937·5 „		0·91	10·5	34038·0
2936·61	0·05	4	2935·8 H. & A.		0·91	10·5	34042·4
2928·74	0·05	4	2928·1 „		0·90	10·6	34133·8
2915·57	0·05	4	2913·8 „		0·90	10·6	34288·0
2852·22	0·03	10nr 6*	2851·2 „		0·88	10·8	35049·6
2848·53	0·15	4n 6*	2847·9 „		0·88	10·8	35095·0
2846·91	0·15	4n 6*	2845·9 „		0·88	10·9	35114·9
2802·80	0·03	10r	2801·6 „		0·87	11·1	35667·5
2798·07	0·03	4	2796·9 „		0·87	11·1	35727·8
2795·63	0·03	10r	2794·1 „		0·87	11·1	35759·0
2790·88	0·03	4	2789·6 „		0·87	11·1	35818·9
2783·08	0·03	8r	2781·8 „		0·86	11·2	35980·2
2781·53	0·03	8r 6†	2780·7 L. & D.		0·86	11·2	35940·2
2779·94	0·03	10r	2779·4 „		0·86	11·2	35960·8
2778·36	0·03	8r 6†	2778·2 „		0·86	11·2	35981·3
2776·80	0·03	8r 6†	2776·9 „		0·86	11·2	36001·5
2768·57	0·15	4n	2767·5 „		0·86	11·2	36108·5
2765·47	0·15	4n	2764·5 „		0·86	11·2	36149·0
2736·84	0·15	2n 7*	2736·0 „		0·85	11·4	36527·1
2733·80	0·15	2n 7*	2732·5 „		0·85	11·4	36567·7
2732·35	0·15	2n 7*	2731·0 „		0·85	11·4	36587·1
2698·44	0·15	2n 7†	2698·0 „		0·83	11·6	37046·9
2695·53	0·15	2n 7†	2695·0 „		0·83	11·6	37086·9
2693·97	0·15	2n 7†	2693·5 „		0·83	11·6	37108·3

MAGNESIUM—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
2672·90	0·20	1n 8*	2672·5 L. & D.		0·83	11·7	37400·8
2669·84	0·20	1n 8*	2670·0 „		0·83	11·7	37443·7
2668·26	0·20	1n 8*	2668·5 „		0·83	11·7	37465·9
2649·30	0·50	1n 8†	2649·0 „		0·83	11·8	37734·0
2646·61	0·50	1n 8†	2646·0 „		0·83	11·8	37772·4
2645·22	0·50	1n 8†			0·83	11·8	37792·2
2633·13	1·00	1n	2633·0 „		0·82	11·9	37965·7
2630·52	1·00	1n	2630·0 „		0·82	11·9	38003·4
(2605·4)			2605·0 „		0·82	12·0	38369·8

The lines marked * and † form a series of triplets, of which the oscillation frequencies (in air) can be calculated (very nearly) from the formula $10^8\frac{1}{\lambda} = a - bn^{-2} - cn^{-4}$, where $a = 39796{\cdot}10$ for the *first* line, 39836·79 for the *second*, and 39857·00 for the *third* line of the triplets, $b = 130398$, $c = 1432090$ in the triplets marked *; and in those marked †, $a = 39836{\cdot}74$ for the *first* line, 39877·95 for the *second*, 39897·91 for the *third*, $b = 125471$, $c = 518781$. The figure preceding the sign * or † shows the value of n.

NOTE.—Lines at
4808·0, 3895·0, 3893·0, 3852·0, 3848·0
3073·5, 3050·6, 3046·7
} are given by Liveing and Dewar.

CALCIUM (ARC SPECTRUM).

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. IV. Berlin, 1891).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
6499·85	0·10	4	6498·3 Å. & Th.	6499·870	1·91	4·5	15380·5
6493·97	0·10	4	6492·4 „	6493·998	1·91		15394·4
6471·85	0·10	4		6471·889	1·90		15447·0
6462·75	0·10	6r	6462·0 „	6462·840§	1·90		15468·8
6449·99	0·10	1	6449·3 „	6450·028	1·90		15499·5
6439·36	0·10	10r	6438·5 „	6439·301	1·89	4·5	15525·0
6169·87	0·10	6		6169·774	1·82	4·8	16203·0
6169·36	0·10	4	6168·0 Thalén	6169·2	1·82		16204·3
6166·75	0·10	4	6165·5 „	6166·6	1·81		16211·2
6163·98	0·10	4	6163·6 „	6163·95	1·81		16218·5
6162·46	0 10	10r 3†		6162·395d	1·81		16222·5
6161·60	0·10	2	6161·1 „	6161·45	1·81		16224·8
6122·46	0·05	10r 3†	6121·2 „	6122·432	1·80		16328·5
6102·99	0·05	8r 3†	6101·2 „	6102·940	1·80	4·8	16380·6
5867·94	0·10	6b^v		5867·78 ?	1·73	5·0	17036·8
5857·77	0·10	10n	5856·4 „	5857·675	1·73	5·0	17066·3
5603·06	0·05	8		5603·099t	1·65	5·3	17842·1

CALCIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5601·51	0·05	8	5600·3 Thalén	5601·45			17847·0
5598·68	0·05	8n	5597·3 „	5598·7			17856·0
5594·64	0·05	10n	5593·4 „	5594·7			17869·9
5590·30	0·05	8	5588·9 „	5588·9			17882·8
5588·96	0·05	10	5587·5 „	5588·976			17883·9
5582·16	0·05	8	5580·9 „	5582·192	1·65	5·3	17908·9
5513·07	0·10	8		5513·194	1·63	5·4	18133·3
5349·66	0·05	10	5348·4 „	5349·6	1·58	5·6	18687·2
5270·45	0·05	10	5269·2 „	5270·497§	1·56	5·6	18968·1
5265·79	0·05	8	5264·6 „	5265·75			18984·9
5264·46	0·05	6	5263·2 „	5264·4			18989·7
5262·48	0·05	6	5261·4 „	5262·4			18996·8
5261·93	0·05	6	5261·0 „	5261·885			18998·8
5260·58	0·05	4		5260·6	1·56	5·6	19003·7
5189·05	0·05	6		5188·947d	1·54	5·7	19265·7
5041·93	0·05	8b^v	5041·0 „	5041·9	1·50	5·9	19827·8
4878·34	0·10	10b^v	4877·3 „	4878·35§	1·45	6·1	20492·7
4847·22	0·20	4b^r	4846·5 „	?	1·44		20624·3
4833·85	1·00	1b^r	4832·5 „	4833·8 ?	1·43		20681·3
4823·04	1·00	1b^r	4822·3 „	?	1·43	6·1	20727·7
4807·47	1·00	1b^r	4806·7 „	4807·4 ?	1·43	6·2	20794·8
4685·40	0·50	4b^r	4684·3 „	4685·4 ?	1·39	6·3	21336·6
4624·71	0·50	1b^r	4622·4 „	4624·7 ?	1·37	6·4	21616·6
4586·12	0·10	10	4585·3 „	4586·1	1·36	6·5	21798·4
4581·66	0·10	8	4580·8 „	4581·7§	1·36	6·5	21819·6
4578·82	0·10	8		4578·723	1·36	6·5	21833·2
4527·17	0·10	6	4526·3 „	4527·1	1·35	6·6	22082·2
4512·73	1·00	1n		4512·5 ?	1·34		22152·9
4509·89	1·00	1n		4509·9 ?			22166·9
4508·04	1·00	1n		4508·1 ?	1·34	6·6	22176·0
4456·81	0·03	4	4456·1 „	4456·8	1·33	6·7	22430·9
4456·08	0·03	8r 4*	4456·3 „	4456·05			22434·5
4454·97	0·03	10r	4454·3 „	4455·0	1·33		22440·1
4435·86	0·03	8r 4*	4435·1 „	4435·9	1·32		22536·8
4435·13	0·03	10r	4434·4 „	4435·1			22540·5
4425·61	0·03	10r 4*	4424·9	4425·6	1·32	6·7	22589·0
4355·41	0·10	6b	4355·0 „	4355·22 ?	1·30	6·9	22953·0
4318·80	0·03	8r		4318·828	1·29		23147·7
4307·91	0·03	8r		4308·023§	1·29		23206·2
4302·68	0·03	10r	4302·1 „	4302·7	1·28		23234·4
4299·14	0·03	6	4298·5 „	4299·15		6·9	23253·6
4289·51	0·03	8r	4289·0 „	4289·6		7·0	23305·7
4283·16	0·03	8r	4282·7 „	4283·15	1·28		23340·2
4240·58	0·10	4	4240·0 „	4240·6	1·27	7·0	23574·7
4226·91	0·03	10r	4226·4 „	4226·9	1·26	7·0	23650·0
4098·82	0·10	4b^v	4098·0 „	4098·8	1·23	7·3	24390·0
4095·25	0·10	2b^v	4094·3 „	4095·1	1·23	7·3	24411·2
4092·83	0·10	2b^v	4092·2 „	4092·9	1·23	7·3	24425·1
3973·89	0·05	6b^v 4†	3972·3 L. & D.	3973·95	1·19	7·6	25156·7
3968·63	0·03	10r	3967·7 „	3968·7	1·19		25190·0
3957·23	0·05	6b^v 4†	3956·0 „	3957·15	1·19		25262·6
3949·09	0·05	4b^v 4†	3947·9 „	3949 2	1·18		25314·7
3933·83	0·03	10r	3933·0 „	3934·	1·18	7·6	25412·9
3737·08	0·03	4	3736·4 „	3737·2	1·13	8·1	26750·7
3706·18	0·03	4	3705·5 „	3706·2	1·12	8·2	26973·8

CALCIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
3653·62	0·05	4		3653·6	1·10	8·3	27361·8
3644·45	0·05	10r 5*	3644·0 L. & D.	3644·5			27430·7
3630·82	0·05	8r 5*	3631·0 „	3630·9		8·3	27533·7
3624·15	0·05	8r 5*	3623·5 „	3624·2	1·10	8·4	27584·3
3487·76	0·05	6b^{v} 5†	3486·5 „	3487·8	1·06	8·7	28663·0
3474·98	0·05	4b^{v} 5†	3474·5 „	3474·95	1·05	8·8	28768·3
3468·68	0·05	4b^{v} 5†	3468·0 „	3468·65	1·05	8·8	28820·6
3361·92	0·10	8b^{r} 6*	3359·5 „	3361·95	1·02	9·1	29735·8
3350·22	0·10	8b^{r} 6*	3347·5 „	3350·3	1·02	9·1	29839·7
3344·49	0·10	6b^{r} 6*	3342·0 „	3344·3 ?	1·02	9·1	29890·8
3286·26	0·10	4b^{r} 6†	3285·0 „	3286·1	1·00	9·3	30420·4
3274·88	0·10	2b^{v} 6†	3273·0 „	3274·8	1·00	9·3	30526·2
3269·31	0·10	2b^{v} 6†	3268·5 „	3269·3	1·00	9·4	30578·1
3225·74	0·50	4b^{r} 7*	3224·5 „	3225·9	0·98	9·5	30991·1
3215·15	0·50	4b^{r} 7*	3213·0 „	3215·3	0·98	9·5	31093·2
3209·68	0·50	2b^{r} 7*	3208·0 „	3209·3 ?	0·98	9·5	31146·2
3181·40	0·03	4 7†	3181·0 „	3181·4	0·97	9·6	31423·1
3179·45	0·03	6	3179·0 „	3179·4		9·6	31442·3
3170·23	0·50	2 7†	3168·5 Cornu	3170·3		9·7	31534·7
3166·95	2·00	1n 7†		3166·9			31566·4
3158·98	0·03	1n	3158·8 L. & D.	3159·0	0·96		31646·1
3150·85	0·50	6 8*	3151·0 „	3150·9			31727·8
3140·91	0·50	2n 8*	3141·0 „	3140·95		9·7	31828·2
3136·09	0·50	2n 8*	3136·0 „	3136·0	0·96	9·8	31887·2
3117·74	1·00	1n 8†	3117·5 „	3117·85	0·95		32064·7
3107·96	1·00	1n 8†	3108·0 „	3107·9		9·8	32171·5
3101·87	1·00	1n 8† 9*		3102·0 ?		9·9	32228·6
3006·95	0·05	4 9*			0·92	10·2	33246·1
2999·76	0·10	4 9*					33325·8
2997·42	0 05	4					33351·8
2995·06	0·05	4			0·92	10·2	33375·1
2398·66	0·05	8r	2398·0 „		0·76	13·1	37676·8
2275·60	0·10	8r			0·73	14·0	43930·4
2200·84	0·10	8r			0·70	14·2	45423·0

The lines marked * and † form a series of triplets, of which the oscillation frequencies (in air) can be calculated, very nearly, from the formula $10^{8}\frac{1}{\lambda}=a-bn^{-2}-cn^{-4}$, where $a=33919{\cdot}51$ for the *first* line, 34022·12 for the *second*, and 34073·82 for the *third* line of the triplet, $b=123547$, $c=961696$, in the triplets marked *; and in those marked † $a=34041{\cdot}17$ for the *first* line, 34146·95 for the *second*, and 34199·09 for the *third*, $b=120398$, $c=346097$. The figure preceding the sign * or † shows the value of n.

§ Double:—calcium and iron. d Double. t Triple.

Zinc (Arc Spectrum).

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. IV. Berlin, 1891).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5182·20	0·10	8b^{v}			1·53	5·7	19286·1
4810·71§	0·03	10r 3†	4809·8 Thalén	4810·68	1·43	6·2	20780·7
4722·26§	0·05	10r 3†	4721·5 „	4722·30	1·40	6·3	21170·0
4680·38§	0·05	10r 3†			1·39	6·3	21359·5
4630·06§	0·10	8b^{v}	4679·6 „	4680·45 ?	1·38	6·4	21591·6
4298·54	0·10	2n		4680·28 ?	1·28	6·9	23256·8
4293·02	0·05	2			1·28	6·9	23286·7
4101·94	0·10	2			1·23	7·3	24371·4
4058·02	0·03	8		4058·10 ?	1·22	7·4	24635·2
4019·75	0·05	4			1·20	7·5	24869·7
3740·12	0·10	4			1·13	8·1	26729·0
3683·63	0·03	8b		3683·70	1·11	8·2	27138·9
3671·71	0·05	6		3671·80 ?	1·11	8·2	27227·1
3572·90	0·03	2			1·08	8·5	27980·0
3515·26	0·20	1n		3515·20 ?	1·07	8·7	28438·7
3346·04§	0·10	4		3346·12	1·02	9·1	29877·0
3345·62§	0·05	8r		3345·72 ?	1·02	9·1	29880·7
3345·13§	0·03	10r 4*	3342·0 L. & D.	3345·10 ?	1·02	9·1	29885·1
3303·03§	0·03	8r 4*		3303·00 ?	1·01	9·3	30265·9
3302·67§	0·03	8r	3301·0 „	3302·72	1·01	9·3	30269·2
3282·42§	0·03	8r 4*	3281·0 „		1·00	9·3	30456·0
3075·99§	0·03	8r			0·94	9·9	32500·0
3072·19§	0·05	10r 4†	3070·0 „		0·94	10·0	32540·1
3035·93§	0·05	10b 4†	3035·0 „		0·93	10·1	32928·7
3018·50§	0·05	8b^{v} 4†	3017·0 „		0·93	10·2	33118·6
2913·63	0·05	4			0·90	10·6	34310·8
2873·39	0·03	6			0·89	10·8	34791·3
2863·43‡	0·03	6			0·89	10·8	34912·3
2833·13	0·03	8r			0·88	10·9	35285 7
2823·27‡	0·03	6			0·88	11·0	35408·9
2802·11	0·03	4r			0·87	11·1	35676·3
2801·00§‡	0·03	10r 5*	2800·0 „		0·87	11·1	35690·4
2781·33	0·20	4b^{r}			0·86	11·2	35942·8
2771·05	0·03	6r			0·86	11·2	36076·2
2770·94§	0·03	8r 5*	2770·0 „		0·86	11·2	36077·6
2756·53§‡	0·10	6r 5*	2756·0 „		0·86	11·3	36266·2
2751·49	0·20	2b^{r}			0·86	11·3	36332·6
2735·96‡	0·20	2b			0·85	11·4	36525·5
2712·60§‖	0·05	8b^{v} 5†	2713·3 „		0·84	11·5	36853·5
2706·64‡	0·05	6			0·84	11·5	36934·7
2697·54	0·10	2b			0·84	11·6	37059·2
2684·29§	0·05	8b^{v} 5†	2684·0 „		0·84	11·6	37242·2
2670·67§	0·05	6b^{v} 5†	2670·5 „		0·83	11·7	37432·1
2663·25	0·05	8			0·83	11·7	37548·1
2623·87	1·00	1n			0·82	11·9	38111·6
2608·65§	0·05	8r 6*	2608·5 „		0·82	12·0	38322·0
2601·03	1·00	2n			0·82	12·1	38434·2
2582·57§‡	0·10	8r 6*	2582·0 „		0·81	12·1	38709·0
2577·34	0·05	4			0·81	12·2	38787·5
2575·15	0·15	2n			0·81	12·2	38820·5
2570·00§	0·10	6r 6*	2569·7 „		0·81	12·2	38898·3

ZINC (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
2567·99	0·10	6b^v 6†			0·81	12·2	38928·8
2562·70	1·00	2n			0·80	12·3	39009·0
2558·03	0·05	4			0·80	12·3	39080·3
2542·53	0·10	6b^v 6†			0·80	12·3	39318·6
2530·34	0·10	2b^v 6†			0·80	12·4	39508·0
2516·00§	0·20	6n 7*	2516·0 L. & D.		0·79	12·5	39723·1
2502·11	0·10	4			0·79	12·6	39950·9
2493·67	0·15	4n 7†			0·79	12·6	40088·9
2491·67§	0·15	6n 7*	2491·5 „		0·79	12·6	40121·1
2479·85§‡	0·15	4b^v 7*	2480·0		0·78	12·7	40312·3
2469·72	0·15	2b^v 7†			0·78	12·8	40477·6
2463·47§	0·20	4n 8*	2464·5 „		0·78	12·8	40580·4
2457·72‡	0·25	1b^v 7†			0·78	12·8	40675·3
2449·76	0·25	1 8†			0·77	12·9	40807·4
2439·94§‡	0·30	4n 8*	2440·0 „		0·77	12·9	40971·7
2430·74§	0·30	1n 8*9*	2430·0 „		0·77	13·0	41126·7
2427·05	0·30	1n 8†			0·77	13·1	41189·2
2415·54	0·30	1n 8†			0·76	13·1	41385·5
2407·98	0·30	1n 9*			0·76	13·2	41515·4
2393·88	0·05	8			0·76	13·3	41759·9
2246·90	0·15	6			0·72	14·2	44491·4
(2138·3)§						14·8	46751·3

The lines marked * and † form a series of triplets, of which the oscillation frequencies (in air) can be calculated (very nearly) from the formula $10^8\frac{1}{\lambda}-a-bn^{-2}-cn^{-4}$, where $a=42945{\cdot}32$ for the *first* line, 43331·71 for the *second*, and 43521·48 for the *third* line of the triplet, $b=131641$, $c=1236125$ in the triplets marked *; and in those marked † $a=42954{\cdot}59$ for the *first* line, 43343·65 for the *second*, and 43533·32 for the *third*, $b=126919$, $c=632850$. The figure preceding the sign * or † shows the value of n.

§ Ames. 4810·7, 4722·3, 4680·3, 4630·1, 3346·2, 3345·7, 3345·1, 3303·1, 3302·8, 3282·35, 3076·1, 3072·1, 3035·9, 3018·5, 2800·9 (double), 2770·9 (double), 2756·5, 2712·6, 2684·2, 2670·7, 2608·7, 2582·5, 2570·0, 2516·2, 2491·6, 2479·9, 2463·7, 2440·4, 2429·0, 2138·3. ‡ See Iron. ‖ See Cadmium.

STRONTIUM (ARC SPECTRUM).

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. IV. Berlin, 1891).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
6550·53	0·20	6	6550·3 Thalén	absent	1·92	4·5	15261·4
6504·17	0·10	4	6501·8 „	6504·35	1·91	„	15370·2
6408·65	0·10	6	6407·3 „	6408·80	1·88	4·6	15599·3
6386·74	0·10	6	6387·3 „	absent	„	„	15652·8
6380·95§	0·10	4	6380·3 „	6380·94	„	4·6	15667·0
5970·38	0·05	4b^v	5970·7 „	5970·27	1·76	4·9	16744·4
5848·01	0·10	1	5850·1 „	absent	1·72	5·0	17094·8
5817·01	0·05	2	5816·0 Huggins	5817·05	1·71	5·1	17185·9

STRONTIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5767·29	0·10	2	5766·0 Huggins	5767·37	1·70	5·1	17334·1
5543·49§	0·05	6b	5543·0 „	5543·30	1·64	5·3	18033·8
5540 28	0·05	6	5540·1 Thalén	absent	„	„	18044·3
5535·01	0·05	6	5533·0 „	5535·05	1·63	„	18061·5
5522·02	0·05	8	5522·6 „	absent	„	„	18104·0
5504·48	0·05	10	5503·6 „	5504·55	„	5·4	18162·6
5486·37	0·05	8	5485·1 „	absent	1·62	„	18221·6
5481·15§	0·03	10	5480·1 „	5481·05	„	„	18239·0
5451·08	0·03	8	5450·0 Huggins	5451·00	1·61	„	18339·6
5257 12	0·03	10	5256·1 Thalén	5257·15	1·56	5·6	19017·2
5238·76	0·03	10	5238·7 „	5238·73	1·55	„	19082·9
5229·52	0·03	8	5228·7 „	absent	„	5·7	19116·5
5225·35	0·03	8	5225·7 „	5225·15	„	„	19131·8
5222·43	0·03	8	5223·7 „	5222·55	1·54	„	19142·5
5213·23	0·03	4	5217·0 Huggins	5213·20	„	„	19176·3
5156·37	0·05	10	5155·0 „	5156·28	1·53	5·8	19387·7
4971 85	0·05	4 4*		absent	1·47	5·9	20107·3
4968·11	0·03	8	4967·6 Thalén	4968·10	„	6·0	20122·4
4962·45	0·03	10r	4961·6 „	4962·55	„	„	20145·3
4892·20	0·03	8	4893·0 Huggins	absent	1·45	6·1	20434·6
4876·35	0·03	8r 4*	4876·1 Thalén	4876·57	„	„	20501·0
4872·66	0·05	10r	4872·1 „	absent	1·44	„	20516·6
4869·41	0·10	4n		4869·68	„	„	20530·3
4868·92	0·03	6n	4865·0 Huggins	absent	„	„	20532·3
4855·27	0·05	6n	4853·0 „	„	„	„	20590·1
4832·23	0·03	10r 4*	4831·6 Thalén	4832·28	1·43	„	20688·3
4812·01	0·03	10r	4812·1 „	4812·22	„	6·2	20775·1
4784·43	0·05	6	4783·6 „	4784·25	1·42	„	20894·9
4755·59	0·10	2	4750·0 Huggins	4755·35	1·41	„	21021·6
4742·07	0·03	6	4740·6 Thalén	absent	„	6·3	21081·5
4729·93	0·10	2n		4729·82Fe	1·40	„	21135·7
4722·42‖	0·03	8	4721·1 „	absent	„	„	21169·3
4678·39‡	0·10	6n		4678·37	1·39	„	21368·6
4607·52	0·03	10r	4607·6 „	4607·51	1·37	6·4	21697·2
4531·54§	0·03	6		absent	1·35	6·6	22061·0
4480·96	0·10	2n		4481·00	1·33	„	22310·0
4438·22	0·03	6n	4437·0 Lockyer	absent	1·32	6·7	22524·9
4412·82	0·03	4		„	1·31	„	22654·6
4361·87	0·03	6n	4365·0 „	„	1·30	6·8	22919·1
4338·00	0·05	6b^{v}	4336·0 „	4338·05	1·29	6·9	23045·2
4326·60	0·03	4	4325·0 „	4326·55	„	„	23105·9
4319·39	0·05	4b^{v}	4319·0 Huggins	absent	„	„	23144·5
4308·49	0·10	2b^{v}		4308·37	„	„	23203·1
4305·60§	0·10	6	4305·3 Thalén	4305·48	„	„	23218·6
4215·66§	0·03	10r	4215·3 „	4215·70	1·26	7·1	23714·1
4161·95	0·03	6	4161·0 „	4161·97	1·25	7·2	24020·0
4077·88	0·03	10r	4078·5 „	4077·90	1·22	7·3	24515·2
4032·51	0·05	4b^{r} 5*	4031·7 Lockyer 4031·5 „	4032·60	1·21	7·4	24791·0
4030·45§	0·05	6b^{r}	4029·4 „	4030·50	„	„	24803·7
3970·15	0·05	4b	3969·1 „	3970·21	1·19	7·6	25180·4
3969·42§	0·05	4 5*		3969·40Fe	„	„	25185·0
3940·91§	0·05	4b^{r} 5*	3939·5 „	3940·80	1·18	„	25367·2
3705·88	0·20	6n 6*	3705·0 L. & D.	3705·80	1·12	8·2	26975·9
3653·90	0·10	2n	3653·0 „	3653·90Fe	1·10	„	27359·8

STRONTIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
3653·32¶	0·10	4n 6*		3653·48	1·10	8·2	27364·2
3629·15	0·10	4 6*		absent	,,	8·3	27546·3
3628·62	0·10	2		,,	,,	8·4	27550·3
3577·45	0·10	1		3577·40	1·08	8·5	27944·4
3547·92	0·30	6n 7*	3547·8 L & D.	3547·92	1·07	8·6	28176·9
3504·70	0·30	2n		3504·80	1·06	8·7	28524·4
3499·40	0·20	6n 7*	3498·0 ,,	?	,,	,,	28567·6
3477·33	0·10	2n 7*		3477·30	,,	8·8	28748·9
3475·01	0·05	6		absent	,,	,,	28768·1
3464·58	0·03	8	3464·0 ,,	3464·60	1·05	,,	28854·7
3457·70	0·20	1n 8*	3458·0 ,,	3457·70	,,	,,	28912·2
3456·78	0·20	1			,,	,,	28919·9
3411·62	0·50	1n 8*			1·04	8·9	29303·7
3400·39	0·00	1n 9*			1·03	9·0	29399·4
3390·09	0·50	1n 8*			,,	,,	29488·7
3380·89	0·03	8	3379·5 ,,	?	,,	,,	29569·0
3366·43	0·03	8	3365·5 ,,	absent	1·02	9·1	29696·0
3351·35	0·05	10r		,,	,,	,,	29829·6
3330·15	0·03	8		3330·08Mg	1·01	9·2	30019·5
3322·32	0·03	8		3322·93	,,	,,	30090·2
3307·64	0·05	10r	3305·2 ,,	,,	,,	,,	30223·8
3301·81	0·05	8		3301·77	,,	,,	30277·2
3200·4§	0·20	2n			0·98	9·6	31236·5
3199·1	0·20	2n			,,	,,	31249·2
3190·1	0·20	2n			0·97	,,	31337·4
3189·4	0·20	2n			,,	,,	31344·2
3182·4	0·50	1n			,,	,,	31412·2
3172·3	0·50	1n			,,	,,	31513·3
2931·98	0·03	8	2931·0 ,,		0·90	10·5	34096·1

* These lines form a series of triplets for which, in the formula $10^8 \frac{1}{\lambda} = a - bn^{-2} - cn^{-4}$, $a = 31030{\cdot}64$ for the *first* line, 31424·67 for the *second*, and 31610·58 for the *third*, $b = 122328$, and $c = 837473$.

§ See Iron. ‖ See Zinc. ‡ See Cadmium. ¶ See Calcium.

CADMIUM (ARC SPECTRUM).

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. IV. Berlin, 1891).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5154·85	0·20	6b^v	5154·2 Thalén	absent	1·53	5·8	19393·4
5086·06	0·05	10r 3†	5086·1 Ames	,,	1·51	,,	19655·8
4800·09	0·05	10r 3†	4800·0 ,,	4800·04	1·42	6·2	20826·7
4678·37	0·05	10r 3†	4678·3 ,,	4678·33	1·39	6·3	21368·7
4662·69	0·10	8b^v		4662·73	1·39	6·4	21440·4
4413·23	0·05	6	4413·1 ,,	absent	1·32	6·7	22652·4
4306·98	0·05	4b		4307·0	1·29	6·9	23211·2
3981·92	0·10	2b^v		absent	1·19	7·6	25105·9

CADMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
3729·21	0·20	4b^v		absent	1·12	8·1	26807·2
3649·74	0·03	2b^v		„	1·10	8·3	27390·9
3614·58	0·10	4	3614·6 Ames	„	1·09	8·4	27657·3
3613·04	0·05	8r 4*	3613·1 „	„	„	„	27669·1
3610·66	0 03	10r	3610·6 „	3610·67	„	„	27687·3
3595·64	0·10	1b^v		absent	„	„	27803·1
3500·09	0 05	4b^v	3499·2 H. & A.	„	„	„	28562·3
3467·76	0·03	8r 4*	3467·7 Ames	„	1·05	8·8	28828·3
3466·33	0·03	10r	3466·15 „	3466·35	„	„	28840·2
3403·74	0·03	10r 4*	3403·7 „	3403·80	1·03	9·0	29370·4
3299·11	0·03	4		3299·12	1·01	9·3	30301·9
3261·17	0·03	10r	3261·1 „		1·00	9·4	30654·4
3252·63	0·05	8b^v 4†	3252·6 „		0·99	„	30734·9
3133·29	0·20	8b^v 4†	3133·2 „		0·96	9·8	31905·5
3081·03	0·10	6b^v 4†	3081·0 „		0·94	9·9	32446·8
3005·53	0·20	1b^v			0·92	10·2	33261·8
2981·46	0·20	4r			„	10·3	33530·3
2980·75	0·03	8r 5*	2980·8§ „		„	„	33538·3
2961·64	0·15				0·91	10·4	33754·7
2908·85	0·50				0·90	10·6	34367·2
2903·24	0·50				„	10·7	34433·6
2881·34	0 03	5*	2881·0§ „		0·89	„	34695·4
2880·88	0·03				„	10·8	34700·8
2868·35	0·03	5†	2868·2 „		„	„	34852·4
2862·56	0·10				„	„	34925·4
2837·01	0·03	5*	2837·0 „		„	10·9	35237·5
2818·66	0·10				0·87	„	35466·9
2775·09	0·03	5†	2775·0 „		0·86	11·2	36023·7
2764·29	0·10				„	„	36164·4
2763·99	0·03	6*	2763·9§ „		„	„	36168·4
2756·69	0·50				„	11·3	36264·1
2748·68	0·03				„	„	36379·8
2733·97	0·05	5†	2748·45 Bell		0·85	11·4	36565·4
2712·65	0 05	6†	2733·8 Ames		„	„	36852·9
2677·65	0·20	6*	2677·6§ „		0·84	11·7	37334·5
2670·81	0·50				0·83	„	37430·1
2660·45	0·20	7†	2660·3 „		„	„	37575·9
2657·10	0·20				„	11·8	37623·2
2654·65	0·20				„	„	37657·9
2639·63	0·10	6*	2639·4 „		„	„	37872·3
2632·29	0·10	7†			0·82	„	37977·9
2629·15	0·10	6†			„	„	38023·3
2601·99	0·30	8*	2602·1 „		„	12·0	38420·1
2592·14	0·10	6†			0·81	12·1	38566·1
2582·86	0·30	8†			„	„	38704·7
2580·33	0·10	7*	2580·2 „		„	12·2	38742·5
2573·12	0·10		2572·95 Bell		„	„	38851·1
2553·61	0·20	7† 9†			0·80	12·3	39148·0
2544·84	0·20	7*	2544·8 Ames		„	12·4	39280·5
2525·57	0 50	8*	2525·3 „		0·79	12·5	39582·5
2521·74	0·50				„	„	39642·7
2507·93	0·50				„	12·6	39860·9
(2491)		8*	2491·0 „				
2474·15	0·50	8†			0·78	12·7	40405·2
2329·35	0·05		2329·22 Bell		0·74	13·7	42916·7

CADMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
2321·23	0·20		2321·14 Bell		0·74	13·7	43066·0
2312·95	0·15		2312·83 „		„	13·8	43221·0
2306·72	0·03		2306·9 L. & D.		0·73	„	43337·8
2288·10	0·05		2288·1 Ames		„	13·9	43690·5
2267·53	0·10		2268·9 H. & A.		0·72	14·1	44086·7
2265·13	0·10	{	2264·88 Bell 2264·42 „	}	„	„	44133·5
2262·36	0·10				„	„	44187·5
2239·93	0·05		2241·7 H. & A.		0·71	14·2	44630·0
2194·67	0·20		2194·6 L. & D.		0·70	14·3	45550·6
2170·11	0·50				„	„	46066·3
2144·45	0·20		2143·75 Bell		0·69	14·4	46617·6

* These lines form a series of triplets for which in the formula $10^8 \frac{1}{\lambda} = a - bn^{-2} - cn^{-4}$, $a = 40755{\cdot}21$ for the *first* line, 41914·60 for the *second*, and 42456·64 for the *third*, $b = 128635$ and $c = 1289619$.

† These lines form a series of triplets for which $a = 40797{\cdot}12$ for the *first* line, 41968 80 for the *second*, and 42510·58 for the *third*, $b = 126146$, $c = 555137$.

§ Double.

BARIUM (ARC SPECTRUM).

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. IV. Berlin, 1891).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
6675·30	0·20	1	6677·0 Huggins	absent	1·96	4·4	14976·2
6595·55	0·10	1	6589·0 „	„	1·94	4·5	15157·2
6527·56	0·10	4	6526·0 Thalén	6527·48	1·92	„	15315·1
6498·93	0·10	4		absent	1·91	„	15382·6
6497·07	0·10	6r	6495·3 „	6497·12	„	„	15387·0
6483·10	0·10	4	6483·0 „	6483·06	1·90	„	15420·2
6451·05	0·10	4	6449·3 „	absent	„	„	15496·8
6341·88	0·10	4	6343·3 „	„	1·86	4·6	15763·6
6141·93	0·03	10r	6140·5 „	6141·96	1·81	4·8	16276·4
6111·01	0·03	6	6109·8 „	absent	1·80	„	16359·1
6083·63	0·15	1		„	1·79	„	16432·7
6063·33	0·03	6	6062·0 „	„	1·78	„	16487·8
6019·69	0·03	6	6018·2 „	6019·60	1·77	4·9	16607·2
5997·31	0·03	4	5991·7 „	absent	„	„	16669·2
5978·72	0·20	1		5978·76	1·76	„	16721·1
5971·94	0·03	8	5971·2 „	absent	„	„	16740·1
5965·06	0·20	2	5971·2 „	5965·15	„	„	16759·4
5907·88	0·05	6	5904·7 „	absent	1·74	5·0	16921·5
5853·91	0·10	10r	5852·7 „	5853·90	1·73	„	17077·6
5826·50	0·03	8r	5827·1 „	absent	1·71	5·1	17157·9
5819·21	0·05	4n		„	„	„	17179·4
5805·86	0·05	6r	5803·6 „	5805·85	„	„	17218·9
5800·48	0·05	6r		absent	„	„	17234·8
5784·24	0·15	2n		5784·26	„	„	17283·3

BARIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5777·84	0·03	10r	5779·6 Thalén	absent	1·70	5·1	17302·4
5721·66	0·30	1n		,,	1·69	5·2	17472·3
5713·62	0·15	4b^v		,,	,,	,,	17496·8
‡5709·82	0·15	4b^v		5709·75	,,	,,	17508·5
5680·34	0·05	6r		5680·48	1·68	,,	17599·4
5620·41	0·50	2n		5620·30	1·66	5·3	17787·0
5593·45	0·10	4n		absent	1·65	,,	17872·7
5535·69	0·05	10r	5534·2 ,,	5535·74	1·64	,,	18059·3
5519·37	0·05	8r	5518·4 ,,	absent	1·63	,,	18112·7
5473·94	0·10	4n			1·62	5·4	18263·0
5437·66	0·10	2n	5436·0 ,,	5474·10	1·61	,,	18384·9
5424·82	0·05	8r	{ 5425·0 ,, 5424·0 ,, }	5424·86	1·60	,,	18428·4
‡5393·47	0·10	1b^v			1·59	5·5	18535·4
5381·25	0·50	1b^v		5381·25	,,	,,	18577·5
5379·05	0·00	1b^v			,,	,,	18585·1
5365·46	0·50	1b^v			,,	,,	18632·2
5309·20	0·30	2b^v			1·57	5·6	18829·6
5305·99	0·20	2b^v		5306·05	,,	,,	18841·0
5302·97	0·20	4b^v			,,	,,	18852·2
5294·40	0·10	2			,,	,,	18882·3
5291·16	0·20	1n			,,	,,	18893·8
5279·72	0·20	1n			1·56	,,	18934·8
5277·84	0·15	4n			,,	,,	18941·5
5267·20	0·10	6n			,,	,,	18979·8
5253·94	0·10	1n			,,	,,	19027·7
5177·60	0·05	2n			1·53	5·7	19308·3
5175·74	0·05	4n			,,	,,	19315·2
5160·27	0·10	4n			,,	,,	19373·1
5055·12	0·10	2n			1·50	5·9	19392·3
4947·50	0·10	2n			1·47	6·0	20206·2
4934·24	0·03	10r	4933·3 ,,	4934·26	1·46	,,	20260·5
4903·11	0·05	6b^v			1·45	,,	20389·2
4900·13	0·05	8	4899·4 ,,	4900·07	,,	,,	20401·6
4877·99	0·15	2n			,,	6·1	20494·1
4726·63	0·05	8r	4727·0 Huggins		1·40	6·3	21150·4
4724·98	0·10	2			,,	,,	21157·8
4700·64	0·05	6b^v		4700·70	,,	,,	21267·4
‡4691·74	0·03	6r	4690·0 ,,	4691·75	1·39	,,	21307·7
4673·69	0·05	6b^r			,,	6·4	21390·0
4642·38	0·10	1b^v		4642·40	1·38	,,	21534·3
4636·80	0·10	2b^v			,,	,,	21560·2
4628·45	0·05	4b^r			,,	,,	21599·1
4620·19	0·05	4b^v			1·37	,,	21637·7
4605·11	0·05	2b^r		4605·20	,,	6·5	21708·5
4600·02	0·05	4b^v	4599·1 Thalén	4600·02	,,	,,	21732·5
4591·88	0·05	2b^r			,,	,,	21771·1
4589·82	0·05	2b^r			1·36	,,	21780·9
4579·84	0·03	8r			,,	,,	21828·3
4574·08	0·05	6r			,,	,,	21855·8
4554·21	0·03	10r	4553·4 ,,	4554·22	1·35	,,	21951·2
‡4525·19	0·05	6	4524·4 ,,	4525·15	,,	6·6	22091·9
4523·48	0·10	6r		4253·58	,,	,,	22100·3
4506·11	0·10	6			1·34	,,	22185·5
4493·82	0·20	4b^r	4493·0 Lockyer	4493·73	,,	,,	22246·2

BARIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
4489·50	0·50	4b^r	4488·0 Lockyer		1·34	6·6	22267·6
4467·36	0·05	4			1·33	6·7	22377·9
4432·13	0·03	6r	4433·0 „	4432·30	1·32	„	22555·8
4413·96	0·05	2		4414·03	„	„	22648·7
4407·10	0·05	4b^v			1·31	„	22684·0
4402·75	0·05	8r	4401·5 „		„	6·8	22706·3
4359·80	0·05	2		4359·80	1·30	„	22930·0
4350·49	0·10	8r	4351·0 „		„	6·9	22979·0
4333·04	0·05	4n	4332·0 „	4333·06	1·29	„	23071·6
4325·38	0·05	2	4325·0 „		„	„	23112·5
4323·15	0·05	4b^r	4323·0 „	4323·15	„	„	23124·4
4291·32	0·05	4	4290·6 „	4291·30	1·28	7·0	23295·8
4283·27	0·03	8r	4282·5 „		„	„	23339·6
4264·45	0·05	4n	4264·0 „	4264·45	1·27	„	23442·7
4242·83	0·05	4b^v	4241·5 „	4242·80	„	„	23562·2
‡4239·91	0·05	2b^v	4239·0 „	4239·90	„	„	23578·4
‡4224·11	0·05	4	4224·0 „		1·26	7·1	23666·5
4179·57	0·20	2b^v		4179·55	1·25	„	23918·8
4166·24	0·05	4	4165·5 „	4166·20	„	„	23995·4
‡4132·60	0·05	2	4131·5 „	4132·58	1·24	7·2	24190·6
4130·88	0·05	8r	4130·5 „	4130·77	„	„	24200·7
4110·46	0·10	2		4110·42	1·23	7·3	24320·8
4087·90	0·50	1n	4087·0 „	4087·96	1·22	„	24455·1
‡4085·35	0·50	1n	4084·0 „	4085·46	„	„	24470·4
4079·56	0·50	1n	4081·0 „	4079·58	„	„	24505·1
‡3995·92	0·10	6	3995·0 „	3995·93	1·20	7·5	25018·0
3993·60	0·03	10r	3992·7 „	absent	„	„	25032·6
3975·55	0·10	2		3975·50	1·19	7·6	25146·2
3938·09	0·05	6	3937·2 „	3938·15	1·18	„	25385·4
‡3935·87	0·05	8r	3934·7 „	3935·95	„	„	25399·7
‡3917·42	0·05	4		3917·45	„	7·7	25519·3
3910·04	0·05	8r	3908·5 L. & D.	3910·06	„	„	25567·4
3906·20	0·05	2		absent	1·17	„	25592·6
3900·54	0·05	4n		„	„	„	25649·8
‡3892·93	0·10	2n		„	„	„	25679·8
3891·97	0·05	6n	3891·0 „	3891·95	„	„	25686·2
3889·45	0·05	4		?	„	„	25702·9
3861·87	0·15	2n		?	„	„	24886·5
3794·77	0·20	2n	3793·5 „	3793·78	1·14	7·9	26344·2
3701·87	0·15	2n		3701·83	1·12	8·2	27005·2
3689·28	0·15	2n		3689·24	1·11	„	27097·4
3664·76	0·10	2n		3664·79	„	8·3	27278·6
3662·62	0·05	6	3660·7 „	absent	„	„	27293·6
3637·10	0·50	1n		3637·16	1·10	„	27486·1
3611·17	0·10	6b^v		3611·18	1·09	8·4	27683·4
3599·60	0·05	6	3598·7 „	absent	„	„	27772·5
3593·58	0·15	4b^v	3592·8 „	?	„	„	27819·0
3588·33	0·10	2n		3588·40	„	8·5	27859·7
3586·64	0·10	2		3586·68	„	„	27872·7
3579·97	0·10	4nr	3579·1 „	3579·97	1·08	„	27924·7
3577·79	0·05	4n		absent	„	„	27941·7
3576·20	0·16	1		„	„	„	27944·1
3566·90	0·05	2n		„	„	„	28027·0
3562·23	0·10	1n		3562·25	„	„	28063·8
3548·14	0·05	2n		3548·15	1·07	8·6	28175·2

BARIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Fraunhofer Lines in Rowland's Map	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda +$	$\frac{1}{\lambda} -$	
3544·94	0·10	6nr	3544·0	absent	1·07	8·6	28200·6
3525·23	0·10	6nr	3524·5	3525·22	,,	,,	28358·3
3501·29	0·05	10r	3499·2	3501·20	1·06	8·7	28552·2
3420·48	0·10	4r	3419·3	absent	1·04	8·9	29226·8
3377·19	0·10	4rb^v	3375·6	3377·29	1·03	9·0	29601·4
3357·00	0·10	6rb^v	3354·8	absent	1·02	9·1	29779·4
3323·06	0·10	4b^v	3320·9	3322·95	1·01	9·2	30383·6
3315·90	0·10	2n		absent	,,	,,	30148·5
‡3298·25	0·10	4b^v		3298·25	,,	9·3	30009·8
3281·96	0·10	4b^v	3279·8	3281·97	1·00	,,	30451·0
‡3262·57	0·10	2b^v	3261·0		,,	9·4	30641·3
3223·11	0·20	1n			0·98	9·5	31016·4
3204·09	0·20	1n			,,	,,	31200·6
3184·45	0·30	1n			0·97	9·6	31393·0
‡3119·48	0·50	1n			0·95	9·8	32046·8
3108·37	0·50	2n			,,	,,	32161·4
3071·71	0·03	6r	3070·3		0·94	10·0	32545·2
2785·22	0·15	8n	2785·1		0·87	11·2	35892·6
2771·51	0·10	6	2771·0		0·86	,,	36070·2
2702·78	0·03	4r	2702·0		0·84	11·5	36987·4
2647·41	0·05	4	2647·0		0·83	11·8	37760·9
2641·52	0·05	4			,,	,,	37845·2
2634·91	0·05	8	2634·5		0·82	11·9	37940·1
2596·89	0·05	4r	2596·7		0·81	12·1	38495·5
2347·67	0·05	6	2347·0		0·75	13·6	42581·8
2335·33	0·05	8r	2335·0		0·74	,,	42807·0
2304·32	0·05	8r	304·5		0·73	13·8	43383·0
2254·80	0·10	4			0·72	14·1	44535·7
2245·72	0·10	4			,,	14·2	44515·0
2216·64	0·10	1			0·70	14·3	45099·0

‡ See Iron.

MERCURY (ARC SPECTRUM).

Kayser and Rünge ('Ueber die Spectren der Elemente,' Pt. IV. Berlin, 1891).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda +$	$\frac{1}{\lambda} -$	
5819·05	0·50	1n	5817 Huggins	1·72	5·1	17179·8
5804·28	0·30	2b^v	5800 ,,	1·71	,,	17223·6
5790·49	0·20	10r	5789·6 Thalén	,,	,,	17264·6
5769·45	0·20	10r	5768·1 ,,	1·70	,,	17327·6
5460·97	0·05	10r 3†	5460·6 ,,	1·61	5·4	18366·4
5365·25	1·00	1n	5364·6 ,,	1·59	5·5	18633·0
4959·74	0·50	2b^v	4958·6 ,,	1·47	6·0	20156·3
4916·41	0·10	6b^v	4916·1 ,,	1·46	,,	20334·0
4358·56	0·03	10r 3†	‡4358·1 ,,	1·30	6·8	22936·6
4347·65	0·10	6b^v	‡4348·0 Hartley & Adeney	,,	6·9	22994·0
4339·47	0·10	4b^v	4341·0 ,,	1·29	,,	24037·4

MERCURY (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
4078·05	0·03	8r 3†	‡4077·5 Hartley & Adeney	1·22	7·3	24514·2
4046·78	0·03	6r	‡4046·5 ,,	1·21	7·4	24703·6
§3984·08	0·05	4	3984·0 ,,	1·20	7·6	25092·3
3908·4	2·00	1n	3910·0 Vogel	1·17	7·7	25578·2
§3820·6	0·50	1n	3820·0 Hartley & Adeney	1·15	7·9	26166·0
§3790·36	0·50	2n	3790·0 ,,	1·14	,,	26374·8
3770·71	0·50	2n	3770·0 ,,	,,	8·0	26512·2
3751·83	0·05	4n	3751·0 ,,	1·13	,,	26645·7
3680·74	0·20	4b^{v}	3681·9 ,,	1·11	8·2	27160·4
3663·25	0·05	6r 4*	‡3662·9 ,,	,,	8·3	27289·9
3654·94	0·05	6r	‡3654·4 ,,	1·10	,,	27351·9
3650·31	0·03	10r	‡	,,	,,	27386·6
3561·53	0·10	4n	3560·1 ,,	1·08	8·6	28069·2
3543·65	0·10	4n	3542·3 ,,	1·07	,,	28210·9
3390·50	0·50	6n	3389·5 ,,	1·03	9·0	29485·2
3367·03	0·50	1n	3365·5 ,,	,,	9·1	29690·7
3351·52	0·10	4b^{r}	3351·2 ,,	1·02	,,	29828·1
3341·70	0·05	6b^{v} 4†	3341·2 ,,	,,	,,	29915·8
3305·23	0·20	1b^{v}		1·01	9·2	30245·9
3264·33	0·20	1		1·00	9·4	30624·8
§3144·61	0·10	2b^{v}		0·96	9·7	31790·7
3135·89	0·20	2n		,,	9·8	31879·1
3131·94	0·03	8r	} 3130·4 ,, }	,,	,,	31919·3
3131·68	0·03	8r 4*		,,	,,	31921·9
§3125·78	0·05	10r	3124·5 ,,	,,	,,	31982·2
3095·35	0·20	1n	3094·0 ,,	0·95	9·9	32296·6
3085·41	1·00	1n		0·94	,,	32400·7
3050·58	0·50	1n		0·93	10·0	32770·6
3038·69	0·15	4b^{v}		,,	10·1	32898·8
3027·62	0·15	2b^{v}		,,	,,	33019·1
3023·71	0·20	2n 5*		,,	,,	33061·8
3021·64	0·05	4r	3021·0 ,,	,,	,,	33084·5
3011·17	0·25	1n		0·92	10·2	33199·5
3007·02	0·15	2b^{r}		,,	,,	33245·3
2967·37	0·10	10r 4*	2966·4 ,,	0·91	10·4	33689·5
§2925·51	0·10	8b^{v} 5†	2925·2 ,,	0·90	10·6	34171·5
2893·67	0·05	6b^{v} 4†	2892·9 ,,	,,	10·7	34547·5
2865·14	0·25	1n		0·89	10·8	34891·5
2857·07	0·10	4b^{v}		,,	,,	34990·1
2847·85	0·10	4n	2846·8 ,,	0·88	10·9	35103·3
2835·26	0·25	1n	2832·1 ,,	,,	,,	35259·2
2819·97	0·10	4n	2819·7 ,,	0·87	11·0	35450·4
§2803·69	0·20	4b^{v} 6*	2804·5 ,,	,,	11·1	35656·2
2799·76	0·20	1	2798·5 ,,	,,	,,	35706·3
§2774·68	0·20	4n	2773·2 ,,	0·86	11·2	36029·0
§2759·83	0·05	6 6†	2760·8 ,,	,,	11·3	36222·8
2752·91	0·03	8b^{v} 4†	2751·5 ,,	,,	,,	36313·9
2699·74	0·40	2n 7*	2702·0 ,,	0·84	11·6	37029·0
2686·61	0·20	2n		,,	,,	37210·0
2675·20	0·20	2n 7†		,,	11·7	37368·7
2672·77	0·20	1n		0·83	,,	37402·7
2660·26	0·20	1n		,,	,,	37578·6
2658·59	0·20	1n	,,	,,	,,	37602·2
2655·29	0·03	6r	2657·6 ,,	,,	11·8	37648·9
2653·89	0·05	6r 5*	‡2652·2 ,,	,,	,,	37668·7

MERCURY (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2652·20	0·05	8r	‡	0·83	11·8	37682·7
2648·12	0·20	1n		,,	,,	37750·8
2642·70	0·10	6b^r	2644·6 Hartley & Adeney	,,	,,	37828·3
2609·73	0·20	1n		0·82	12·0	38306·1
2605·29	0·10	2n	2602·3 ,,	,,	,,	38371·4
§2576·31	0·10	8b^v 5†	2575·3 ,,	0·81	12·2	38803·0
2564·14	0·10	1		0·80	,,	38987·2
2540·39	0·10	2r		,,	12·4	39351·6
2536·72	0·20	10rb	2535·8 ,,	,,	,,	39408·6
2534·89	0·05	8r 5*	2533·8 ,,	,,	,,	39437·0
2524·80	0·10	2b^v	2522·7 ,,	0·79	12·5	39594·6
2505·00	0·50	1n		,,	12·6	39907·6
2482·14	0·20	4n 6*	2484·2 ,,	0·78	12·7	40274·1
2478·09	0·50	2n	2477·7 ,,	,,	,,	40341·0
2464·15	0·05	6b^v 5†	2463·7 ,,	,,	12·8	40569·1
2446·96	0·10	6b^v 6†		0·77	12·9	40854·1
2412·31	0·10	4b^v		0·76	13·2	41440·8
2399·64	0·20	4n 7*		,,	,,	41659·7
2378·40	0·15	6b^v 6*		0·75	13·3	42031·8
2374·10	0·50	2n		,,	13·4	42107·8
2345·41	0·05	4b^v 6†	2342·2 ,,	,,	13·6	42622·9
2301·57	1·00	1b^v 7*		0·73	13·9	43434·7
2262·23	0·15	4	2263·3 ,,	0·72	14·1	44190·1
2260·36	0·15	4	2261·4 ,,	,,	,,	44226·6
2252·87	0·15	2	2254·0 ,,	,,	14·2	44373·6
2224·73	0·20	4	2225·7 ,,	0·71	14·3	44935·0

The lines marked * form a series of triplets for which in the formula $10^8 \frac{1}{\lambda} = a - bn^{-2} - cn^{-4}$, $a = 40159{\cdot}60$ for the *first* line, 44792·87 for the *second*, and 46560·78 for the *third*, $b = 127484$, $c = 1252695$. For the triplets marked † $a = 40217{\cdot}98$, or 44851·01, or 46618·44, $b = 126361$, $c = 613268$.

‡ Ames (Rowland's scale) (*Phil. Mag.*, July 1890), 4451·09, 4358·50, 4347·71, 4077·98, 4046·67, 3663·41, 3663·03, 3654·96, 3650·28, 2653·80, 2652·15. § See Iron.

BROMINE (ABSORPTION).

Hasselberg, 'Kongl. Svenska Vetenskaps-Akademiens Handlingar,' Bandet 24, No. 3, 1891.

* Double. † Triple.

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
			6158·79	4	16232·1
			6158·09	7	16234·0
Group 6162–6142			6157·30	5	16236·1
6161·97	4	16223·8	6157·06		16236·7
6160·64	5	16227·3	6156·78	5	16237·5
6160·00	3	16229·0	6156·55		16238·1
6159·69	3	16229·8	6156·25	4	16238·8
6159·34	4	16230·7	6155·73	4	16240·2
6159·03	2	16231·5	6155·45	7	16241·0

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
6154·92	3	16242·4	6131·92	3	16303·3
6154·58	3	16243·3	6131·59	4	16304·2
6154·19	6	16244·3	6131·19	3	16305·2
6153·36	3	16246·5	6130·78	3	16306·3
6153·00	5	16247·4	6130·41	4	16307·3
6152·64	4	16248·4	6130·08	3	16308·2
6152·39	3	16249·0	6129·69	4	16309·2
6151·96 }	5	16250·2	6129·31	3	16310·2
6151·68 }		16250·9	6128·97	3	16311·2
6151·27 }	4	16252·0	6128·52	3	16312·4
6151·04 }		16252·6	6128·22	4	16313·1
6150·57	6n	16253·8	6127·86	3	16314·1
6149·89	3	16255·6	6127·59	3	16314·8
6149·53	4⊙	16256·6	6127·40	2	16315·3
6149·29	4	16257·2	6127·21	2	16315·8
6148·96	2	16258·1	6126·96	3	16316·5
6148·64	2	16259·0	6126·73	2	16317·1
6148·36	2	16259·7	6126·51	3	16317·7
6148·15	6⊙	16260·2	6126·21	4	16318·5
6147·36	2	16262·3	6125·69	4	16319·9
6147·11	5	16263·0	6125·36	2	16320·8
6146·76	2	16263·9	6125·12	6	16321·4
6146·23	3	16265·3	6124·54	5	16323·0
6145·97	4n	16266·0	6124·01	6	16324·4
6144·91	4	16268·8	6123·50	5	16325·7
6144·25		16270·6	6123·02	5	16327·0
6143·81	4n } b	16271·7			
6143·53	3n }	16272·5			
6143·19	3n } b	16273·4	Group 6122–6103		
6142·84	5n }	16274·3			
			6122·47	⊙	16328·5
			6122·00	0	16329·7
Group 6142–6122			6121·60	4	16330·8
			6121·15	4	16332·0
6141·37	4	16278·2	6120·77	4	16333·0
6141·09	2	16278·9	6120·57	2	16333·5
6140·81	3	16279·7	6120·14	2	16334·7
6140·48	2	16279·6	6119·97	2	16335·1
6140·16	3	16281·4	6119·66	3	16336·0
6139·84	4	16282·3	6119·36	3	16336·8
6139·56	3	16283·0	6119·09	4	16337·5
6139·16	2	16284·1	6118·77	3	16338·3
6138·84	4	16284·9	6118·45	3	16339·2
6138·55	2	16285·7	6118·10*	3	16340·1
6138·24	2	16286·5	6117·61	7	16341·4
6137·64	2	16287·1	6117·23	4	16342·5
6136·42	2	16291·3	6116·47	6⊙ } b	16344·5
6136·11	4	16292·2	6115·67	4 }	16346·6
6135·70*	3	16293·3	6115·26 }	n	16347·7
6135·21	4	16294·6	6114·80 }		16349·0
6134·78	4	16295·7	6114·37	3	16350·1
6134·37	4	16296·8	6114·05	5n	16351·0
6133·98	4	16297·8	6113·44	5n	16352·7
6133·53	4	16299·0	6112·70 }	5 }	16354·6
6133·13	3	16300·1	6112·47 }	} b	16355·2
6132·73	4	16301·2	6112·17	2 }	16356·0
6132·34	4	16302·2	6111·90	4 }	16356·7

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
6111·36	4	16358·2	6091·30	2	16412·1
6111·13	5 b	16358·8	6091·08	3	16412·6
6110·84	2 b	16359·6	6090·81	2	16413·4
6110·51	4	16360·4	6090·58	5	16414·0
6109·76	5	16362·4	6090·15	2	16415·2
6109·45	2 b	16363·3	6089·83*	5	16416·0
6109·16	4	16363·1	6089·31	4	16417·4
6108·49	6⊙	16365·9	6088·79	3	16418·8
6108·18	2	16366·7	6088·53	3	16419·5
6107·90	4	16367·4	6088·12	5	16420·6
6107·44	2	16368·7	6087·56	2	16422·1
6107·22	4s	16369·3	6087·26	3	16422·9
6106·95	3s	16370·0	6087·01	2	16423·6
6106·62*	3	16370·9	6086·79	4	16424·2
6106·27	3	16371·8	6086·39		16425·3
6105·95	4	16372·7	6086·20	4	16425·8
6005·61	3	16373·6	6085·92	2	16426·6
6005·34	3	16374·3	6085·57	6	16427·5
6005·06	4b	16375·1	6085·32	3	16428·2
6004·37	(4 lines)	16376·9	6085·02	4s	16429·0
6004·02	3	16377·8	6084·78	4s	16429·6
6003·57	4	16378·0	6084·54	2	16430·3
			6084·31	4s	16430·6
Group 6103–6079			6084·07	4	16431·6
			6083·75	4	16432·4
6103·24	3	16379·9	6083·20	8	16433·9
6102·76	2	16381·2	6082·50*	6	16435·8
6102·04	5	16383·2	6082·03	4	16437·1
6101·61	3	16384·3	6081·75	5	16437·8
6101·26	4	16385·3	6081·52	4	16438·5
6100·92	3	16386·2	6081·10	4	16439·6
6100·64	4	16386·9	6080·93	5	16440·0
6100·21	5n	16388·1	6080·36	7	16441·6
6099·77	4	16389·3	6079·78	6	16443·2
6099·47	3n	16390·1	6079·11	5	16445·0
6099·12	4n	16391·0			
6098·74	5	16392·0			
6098·33	4	16393·1	Group 6079–6066		
6097·97	4b	16394·1	6078·54	5	16446·5
6097·21	(3 or 4 lines)	16396·1	6078·32		16447·1
6096·48	4	16398·1	6077·85	6	16448·4
6095·95	3	16399·5	6077·49	2	16449·4
6095·74	3	16400·1	6077·23	6	16450·1
6095·50	3	16400·7	6076·83	3	16451·1
6095·04	3b	16402·0	6076·42	3	16452·3
6094·70	4	16402·9	6076·14	3	16453·0
6094·51		16403·4	6075·67	4	16454·3
6094·01	4	16404·7	6075·39	4	16454·9
6093·70	3	16405·6	6075·06*	4	16455·8
6093·46	2	16406·2	6074·73	4	16456·7
6093·22	4	16406·9	6074·39	4	16457·7
6092·76	2	16408·1	6074·12	4	16458·4
6092·50	2	16408·8	6073·86	3	16459·1
6092·25	3	16409·5	6073·44	5	16460·2
6092·01	3	16410·1	6073·08	4	16461·2
6091·78	3	16410·8	6072·72	4	16462·3
6091·52	3	16411·5	6072·35	4	16463·2

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
6071·96	3	16464·2	6050·41	5	16522·9
6071·65	3	16465·1	6049·97	4	16524·1
6071·31	5	16466·0	6049·73	4	16524·7
6070·95	2	16467·0	6049·42	4	16525·6
6070·68	3	16467·7	6049·13	3	16526·4
6070·47	5	16468·3	6048·76	5	16527·4
6070·14	3	16469·2	6048·43	4	16528·3
6069·61	6n	16470·6	6048·10	3	16529·2
6069·02	2	16472·2	6047·80	4	16530·0
6068·75	4	16473·0	6047·42	4	16531·1
6068·50	3	16473·6	6047·09	4	16532·0
6067·75	5	16475·7	6046·75	4	16532·9
6067·19	3	16477·2	6046·46	5	16533·7
6066·86	4	16478·1	6046·14	2	16534·7
6066·41	3	16479·3	6045·82	4	16535·4
6066·07	5s	16480·2	6045·55 }	4	16536·2
			6045·15 }		16537·3
			6044·91	3	16537·9
Group 6066–6042			6044·58	4	16538·8
6065·29	5	16482·4	6044·31	3	16539·6
6064·96	3	16483·3	6044·00	4	16540·4
6064·50	6	16484·5	6043·66	3	16541·4
6063·62	5	16486·9	6043·38	3	16542·1
6062·85	4	16489·0	6043·05	4	16543·0
6062·39	3	16490·2	6042·69	2	16544·0
6062·13	4	16491·0			
6061·88	4	16491·6			
6061·52*	4	16492·6	Group 6042–6003		
6061·22	3	16493·4	6042·20 }	4	16545·4
6060·70	4s	16494·8	6041·79 }		16546·5
6060·32	3	16495·9	6041·54	3	16547·2
6059·97	3	16496·8	6041·28	4	16547·9
6059·64	2	16497·7	6040·96	2	16548·8
6059·36	3	16498·5	6040·56	4	16549·9
6059·05	3	16499·3	6040·16	4	16550·9
6058·72	4s	16500·2	6039·74	5	16552·1
6058·38	2	16501·2	6039·42	5	16553·0
6058·11	2	16501·9	6038·97	4	16554·2
6057·80	3	16502·7	6038·60	4	16555·2
6057·49	3	16503·6	6038·16	5	16556·4
6057·09	4	16504·7	6037·86	5	16557·3
6056·86	4	16505·3	6037·43	4	16558·4
6055·95	6	16507·8	6037·09	4	16559·4
6055·76	6	16508·3	6036·70	5	16560·4
6055·22	6	16509·8	6036·36	5	16561·4
6054·78	6	16511·0	6035·91	4	16562·6
6054·25	6	16512·4	6035·53	4	16563·6
6054·04	3	16513·0	6035·22	4	16564·5
6053·74	4	16513·8	6034·88	3	16565·4
6053·34 }	5	16514·9	6034·55	3	16566·3
6052·70 }		16516·6	6034·29	4	16567·0
6052·47	5	16517·3	6033·94	3	16568·0
6052·12	4	16518·2	6033·71	3	16568·6
6051·82	4	16519·0	6033·52	3	16569·2
6051·37	5	16520·3	6033·26	3	16569·9
6051·01	4	16521·3	6033·01	2	16570·6
6050·74	4	16521·0	6032·75	2	16571·3

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
6032·49	4	16572·0	6007·25	2	16641·6
6032·13	4	16573·0	6007·00 }	4b	16642·3
6031·88	4	16573·7	6006·81 }		16642·9
6031·33	4	16575·2	6006·53 }	5b	16643·6
6030·95	4n	16576·2	6006·34 }		16644·2
6030·25	3	16578·2	6006·07	4	16644·9
6029·87*	5	16579·2	6005·83	4	16645·6
6029·47	3	16580·3	6005·61	4	16646·2
6029·17 }	5	16581·1	6005·32	4	16647·0
6028·72 }		16582·4	6005·10	4	16647·6
6028·22	3	16583·7	6004·84	4	16648·3
6027·67	4	16585·3	6004·60	2	16649·0
6027·08	3	16586·9	6004·35	4	16649·7
6026·79	4	16587·7	6004·00	4	16650·7
6026·52	2	16588·4	6003·66	4	16651·6
6026·15	2	16589·4			
6025·80	5n	16590·4	Group 6003–5977		
6025·19	2	16592·1			
6024·90 }	5	16592·9	6003·28	4	16652·7
6024·72 }		16593·4	6002·70	3	16654·3
6023·87	5	16595·7	6002·38	3	16655·2
6022·93	5	16598·3	6002·11	2	16655·9
6022·43	2	16599·7	6001·83*	3	16656·7
6022·00	6	16600·9	6001·47	3	16657·7
6021·58	3	16602·0	6000·97	3	16659·1
6021·02	6n	16603·6	6000·55*	2	16660·2
6020·15	6n	16606·0	6000·00	3	16661·8
6019·69	3	16607·3	5999·61	4	16662·8
6019·41 }	5	16608·0	5999·15*	2	16664·1
6018·92 }		16609·4	5998·72	3	16665·3
6018·66	4	16610·1	5998·29	3	16666·5
6018·40	6	16610·8	5997·94*	4	16667·5
6017·73	6n	16612·7	5997·42	3	16668·9
6017·18 }	6b	16614·2	5997·05	3	16670·0
6016·56 }		16615·9	5996·72*	4	16670·9
6015·97	4	16617·5	5996·30*	4	16672·0
6015·60	3	16618·5	5995·88	3	16673·2
6015·27	4	16619·4	5995·50	3	16874·3
6014·64	3b	16621·2	5995·11	5	16675·4
6014·45	3b	16621·7	5994·63	4	16676·7
6014·15	4b	16622·6	5994·24	4	16677·8
6013·46	6	16624·5	5993·86	4	16678·8
6013·00	5b	16625·7	5993·54	4	16679·7
6012·36	5b	16627·5	5993·10	4b	16680·9
6011·98	3	16628·5	5992·60	4n	16682·3
6011·73	5	16625·9	5992·12	4n	16683·7
6011·28 }	6	16630·5	5991·63	5n	16685·0
6011·02 }		16631·2	5991·18	4	16686·3
6010·47	5b	16632·7	5990·88	3	16687·1
6010·10	2	16633·8	5990·57	4	16688·0
6009·80	4	16634·6	5990·23	3	16688·9
6009·50	2	16635·4	5989·92	3	16689·8
6009·23	4s	16636·2	5989·59	3	16690·7
6008·61	4	16637·9	5989·32	3	16691·5
6008·26	6	16638·8	5989·00	4	16692·4
6008·03	6	16639·5	5988·64	2	16693·4
6007·56	4	16640·8	5988·43	2	16693·0

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5988·17	3	16694·7	5967·42	4	16752·8
5987·64	3	16696·2	5967·00	4⊙	16753·9
5987·15	3	16697·5	5966·72	4	16754·7
5986·91	3	16698·2	5966·29	6b⊙	16755·9
5986·67	3	16698·9			16756·7
5986·16	3	16700·3	5965·62 }	4	16757·8
5985·95 }	4	16700·9	5965·41 }		16758·4
5985·36 }	(4 lines)	16702·5	5964·97	6	16759·6
5984·79	4	16704·1	5964·35	6	16761·4
5984·50	3	16704·9	5962·95*	5	16765·2
5984·31	2	16705·5	5962·39	5	16766·9
5983·67	3	16707·2	5962·02	5	16767·9
5983·37	4	16708·1	5961·44	6	16769·6
5982·98	2	16709·2	5961·06	6	16770·6
5982·65	6	16710·1	5960·54	6b	16772·1
5982·34	6	16711·0	5960·16	6	16773·2
5981·55	6	16713·2	5959·61	5	16774·7
5981·30	6	16713·9	5959·22	6	16775·8
5980·59	5	16715·9	5958·61	5	16777·5
5980·25	6	16716·8	5958·32	6	16778·4
5979·62 }	4b	16718·6	5957·82	5	16779·8
5979·18 }		16719·8	5957·46	5	16780·8
5978·84	4	16720·7	5956·84	5	16782·5
5978·55 }		16721·6	5956·38	3	16783·8
5978·33 }	4	16722·2	5956·03	4n	16784·8
5978·12 }		16722·7	5955·50	4	16786·3
5977·61	3	16724·2	5955·16	4	16787·3
5977·34	3	16724·9	5954·94	3	16787·9
			5954·52	4	16789·1
			5954·23	3	16789·9
Group 5977–5949			5954·00	2	16790·5
5976·88	2	16726·2	5953·74	4	16791·3
5976·67	2	16726·8	5953·47	4	16792·0
5976·41	3	16727·5	5953·13*	4	16793·0
5976·17	3	16728·2	5952·24	3s	16795·5
5975·95	2	16728·8	5951·97	4s	16796·3
5975·44	4	16730·3	5951·61	2	16797·3
5975·18	4	16731·0	5951·24	4s	16798·3
5974·89	4	16731·8	5950·90	2	16799·3
5974·62	4	16732·6	5950·61	3	16800·1
5974·34	4	16733·3	5950·41	3	16800·7
5973·95	3	16734·4	5950·16	2	16801·4
5973·67	4	16735·2	5949·96	2	16801·9
5973·15	3	16736·7	5949·82	2	16802·3
5972·81	4	16737·6	5949·61	4s	16802·9
5972·52	2	16738·4	5949·27	2	16803·9
5971·97	4	16740·0			
5971·64	3	16740·9			
5971·22	4	16742·1	Group 5949–5935		
5970·86	2	16743·1	5948·67	4	16805·6
5970·45	4s	16744·2	5948·18*	5b	16806·0
5970·09	2	16745·3	5947·53	4	16808·8
5969·68	4s	16746·4	5947·24	2	16809·5
5969·41	2	16747·2	5946·95	3	16810·4
5968·92	4s	16748·5	5946·64	2	16811·3
5968·18	3s	16750·6	5946·40	3	16811·0
5967·66	4	16752·1	5946·09	3	16812·9

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5945·82	5	16813·6	5924·98	4	16872·7
5945·07*	4	16815·8	5924·62	6	16873·7
5944·59	5	16817·1	5924·23	8	16874·8
5943·92	5	16819·0	5924·00	8	16875·5
5943·42	5	16820·4	5923·49	3	16876·9
5943·00	4	16821·6	5923·20	4	16877·8
5942·73	6	16822·3	5923·01	2	16878·3
5942·28	5	16823·6	5922·80	4	16878·9
5941·98	4	16824·4	5922·51	3	16879·7
5941·67	5	16825·3	5922·11	5	16880·9
5941·14	5	16826·8	5921·76	2	16881·9
5940·78	2	16827·8	5921·44	4	16882·8
5940·54	4	16828·5	5921·17	5	16883·5
5940·02	4	16827·5	5920·86	2	16884·4
5939·60	3	16831·1	5920·64	4	16885·1
5939·26	5	16832·1	5920·03	4	16886·8
5938·90	5	16833·1	5919·69	3	16887·8
5938·49	3	16834·3	5919·40	4	16888·6
5938·22	4	16835·1	5919·09	3	16889·5
5937·91	4	16835·9	5918·79	4	16889·3
5937·52	4	16837·0	5918·54	4	16891·1
5937·22	4	16837·9	5918·33	2	16891·7
5936·87	4	16838·9	5918·07*	4	16892·4
5936·65		16839·5	5917·73	3	16893·4
5936·20	4	16840·8	5917·52	4	16894·0
5935·87	4	16841·7	5917·29	3	16894·6
5935·58	3	16842·5	5917·08	3	16895·2
5935·23	4	16843·5	5916·85	3	16895·9
			5916·60	5	16896·6
Group 5935–5896 (D_1)			5916·36	4	16897·3
5934·60	2	16845·3	5916·13	3	16897·9
5934·26	4	16846·3	5915·92	4	16898·5
5933·92	4	16847·3	5915·57	3 b	16899·5
5933·64	2	16848·1	5915·32	4	16900·2
5933·36	5	16848·9	5915·06	2	16901·0
5933·04	5	16849·8	5914·86	4	16901·6
5932·74	3	16850·6	5914·47	?	16902·7
5932·43	5	16851·5	5914·17	2	16903·5
5932·05	4	16852·6	5913·88*	3	16904·4
5931·83	4	16853·2	5913·47	4	16905·5
5931·55	4	16854·0	5913·21		16906·3
5931·10	4	16855·3	5912·96	3	16907·0
5930·78	3	16856·2	5912·53	3	16908·2
5930·53	4	16856·9	5912·31	2	16908·9
5930·22	4	16857·8	5912·00	3	16909·7
5929·33	6	16860·3	5911·81	3 b	16910·3
5928·88	3	16861·6	5911·01		16912·6
5928·60	4	16862·4	5910·74	2	16913·3
5928·03	4	16864·0	5910·18	3	16914·1
5927·74	3	16864·8	5910·21	2	16914·9
5927·46	2	16865·6	5909·95	2	16915·6
5927·15	5 b	16866·5	5909·79	2	16916·1
5926·72	4	16867·7	5909·54	2	16916·8
5926·42	5	16868·6	5909·24	2	16917·6
5926·10	5	16869·5	5908·91	2	16918·6
5925·63	5	16870·8	5908·59	2	16919·5
5925·32	5	16871·7	5908·29	2	16920·4

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5907·94	4	16921·4	5888·37	2	16977·6
5907·68	4	16922·1	5888·10	4	16978·4
5907·38	2	16923·0	5887·81	2	16979·2
5907·09	2	16923·8	5887·53	3	16980·0
5906·75	4	16924·8	5887·27	3	16980·8
5906·13*	8	16926·6	5887·00	5	16981·6
5905·73	2	16927·7	5886·59	3	16982·8
5905·50	4	16928·4	5886·12	4	16984·1
5905·22	2	16929·2	5885·81	3	16985·0
5904·94	5s	16930·0	5885·45	4	16986·0
5904·36	6	16931·6	5885·04	5	16987·2
5904·02	3	16932·6	5884·66	3	16988·3
5903·69	6	16933·6	5884·30	4	16989·4
5903·11	4n	16935·2	5883·90	4	16990·5
5902·73	4	16936·3	5883·54	4	16991·6
5902·44	4	16937·1	5883·13	4	16992·7
5902·13	4	16938·0	5882·78	3	16993·8
5901·82	5⊙	16938·9	5882·36*	5	16995·0
5901·43	4	16940·0	5882·04	4	16995·9
5901·12	2	16940·9	5881·63	4	16997·1
5900·75	3	16942·0	5881·34	4	16997·9
5900·31	4	16943·3	5880·96	4	16999·0
5899·93	2	16944·3	5880·71	3†	16999·7
5899·66	4s	16945·1	5880·33		17000·8
5899·31	4	16946·1	5880·08	3	17001·6
5898·45*	6	16948·6	5879·77*	3	17002·5
5898·06	5	16949·7	5879·44	5s	17003·4
5897·83	4	16950·4	5879·09	4	17004·4
5897·50	5	16951·3	5878·75	4	17005·4
5897·10	5	16952·5	5878·46	4	17006·3
5896·78	5	16953·4	5878·18	4	17007·1
			5877·89	4	17007·9
Group 5896	(D_1)–5862		5877·60	4	17008·7
			5877·12	4	17010·1
5895·95	3	16955·8	5876·81	3	17011·0
5895·68	3	16956·6	5876·52	4	17011·9
5895·34	3	16957·5	5876·27	4	17012·6
5895·01	4	16958·5	5876·01	4	17013·3
5894·61	3	16959·6	5875·74	4	17014·1
5894·37	3	16960·3	5875·47	4	17014·9
5894·11	2	16961·1	5875·26	3	17015·5
5893·86	3	16961·8	5875·10	3	17016·0
5893·62	3	16962·5	5874·87	4	17016·7
5893·37	3	16963·2	5874·62	3	17017·4
5892·95	2	16964·4	5874·37	2	17018·1
5892·71	3	16965·1	5874·14	4 b	17018·8
5892·34	4	16966·2	5873·56	5	17020·4
5891·98	4	16967·2	5873·00	4	17022·1
5891·43*	4	16968·8	5872·71	3	17022·9
5891·04	3	16969·9	5872·52	3	17023·5
5890·81	2	16970·6	5872·31	3	17024·1
5890·57	3	16971·3	5872·09	3	17024·7
5889·64	4	16974·0	5871·90	2	17025·3
5889·15	4	16975·4	5871·65	4	17026·0
5889·00	3	16975·8	5871·19*	4	17027·3
5888·74	3	16976·6	5870·83	3	17028·4
5888·56	3	16977·1	5870·53	3	17029·2

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5870·23	2	17030·1	5849·46	3	17090·6
5869·91	7s	17031·0	5849·17	4	17091·4
5869·46	4	17032·3	5848·83	5	17092·4
5868·93	3	17033·9	5848·55	4	17093·2
5868·58*	5	17034·9	5847·90	4	17095·1
5868·17	4	17036·1	5847·67	2	17095·8
5867·87	2	17037·0	5847·40 }	4	17096·6
5867·59	3	17037·8	5847·18 }		17097·2
5867·37	3 } b	17038·4	5846·93	2	17098·0
5866·75	3 }	17040·2	5846·59	5	17099·0
5866·00	4	17042·4	5846·34	6	17099·7
5865·72	4	17043·2	5846·06	2	17100·5
5865·41	2	17044·1	5845·82	4	17101·2
5865·08	3	17045·1	5845·52	5	17102·1
5864·83	4	17045·8	5845·23	?	17103·0
5864·57	3	17046·5	5844·78	6	17104·3
5864·27	3	17047·4	5844·50	2	17105·1
5863·95	3	17048·3	5844·22	5	17105·9
5863·66	3	17049·2	5843·93	4	17106·8
5863·31	4	17050·2	5843·44	6	17108·2
5863·03	1	17051·0	5843·10	5	17109·2
			5842·82	3	17110·0
			5842·58	3	17110·7
Group 5862–5832			5842·39	2	17111·3
			5842·12	3	17112·1
5862·38	4	17052·9	5841·81	4	17113·0
5862·11	4	17053·7	5841·60	2	17113·6
5861·59	3	17055·0	5841·34	2	17114·4
5861·30	3	17056·1	5841·08	4	17115·1
5861·05	3	17056·8	5840·86	3	17115·8
5860·76	3	17057·6	5840·66	3	17116·4
5860·52	3	17058·3	5840·46	4	17116·9
5860·23	3	17059·2	5840·06	3	17118·1
5859·57	2	17061·1	5839·73	3	17119·1
5859·37	2	17061·7	5839·44	3	17119·9
5859·11	3 } b	17062·4	8539·19	3	17120·7
5858·41	3 }	17064·5	5838·81	6	17121·8
5857·38*	3	17067·5	5838·61	3	17122·4
5856·97	4	17068·7	5838·16	7	17123·7
5856·60	3	17069·7	5837·59	7	17125·3
5856·35	4	17070·5	5837·16	3	17126·6
5855·51	4s	17072·9	5836·95	6	17127·2
5855·36	3s	17073·4	5836·41	7b	17128·8
5854·95*	6	17074·6	5835·92	4	17130·1
5854·52	3	17075·8	5835·66	2	17130·9
5854·00	4⊙	17077·3	5835·44	2	17130·6
5853·43	5	17079·0	5835·15	4	17132·4
5852·90	5	17080·5	5834·89	3	17133·2
5852·56	4⊙	17081·5	5834·56	2	17134·1
5851·90	4	17083·5	5834·20*	4	17135·2
5851·59	3	17084·4	5833·80	5	17136·4
5851·32	4	17085·2	5833·49	4	17137·3
5851·03	2	17086·0	5833·25	2	17138·0
5850·75	5	17086·8	5833·00	3	17138·7
5850·41	3	17087·8	5832·75	2	17139·5
5850·07	4	17088·8	5832·43	6	17140·4
5849·74	5	17089·8	5832·18	3	17140·9

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
Group 5832–5807			5812·18*	6	17200·1
			5811·79	3	17201·3
5831·60	3	17142·9	5811·54	4	17202·0
5831·37 }	4	17143·5	5811·16	3	17203·2
5831·09 }		17144·3	5810·92	3	17203·9
5830·89	4	17144·9	5810·62	5	17204·8
5830·53	3	17146·0	5810·37	4	17205·5
5830·22*	4	17147·9	5809·84	5	17207·1
5829·85	4s	17148·0	5809·57	6⊙	17207·9
5829·59	4s	17148·8	5809·23	2	17208·9
5828·60	6n	17151·7	5808·87*	6	17209·9
5827·69	3	17154·3	5808·45	3	17211·2
5827·42	2	17155·1	5808·15	6	17212·1
5827·13	3	17156·0	5807·95	6	17212·7
5826·71	2	17157·2	5807·54	3	17213·9
5826·43	2	17158·1	5807·35	4	17214·5
5826·19	4	17158·8			
5825·98	2	17159·4			
5825·74	3	17160·1	Group 5807–5791		
5825·28	3	17161·5	5806·83	2	17216·0
5825·04	3	17162·2	5806·60	4	17216·7
5824·77	3	17163·0	5806·38	4	17217·3
5824·27	3	17164·4	5806·02*	3n	17218·4
5823·88	4	17165·6	5805·60	4	17219·6
5823·56	3	17166·5	5805·36	4	17220·4
5823·34	4	17167·2	5805·10	3	17221·1
5823·10	2	17167·9	5804·91	3	17221·7
5822·91 }	4b	17168·4	5804·60	3	17222·6
5822·42 }		17169·9	5804·35	2	17223·4
5822·04	2	17171·0	5804·08	3	17224·2
5821·81	2	17171·7	5803·87	2	17224·8
5821·56	3	17173·4	5803·64	4	17225·5
5821·38	2	17173·0	5803·29	4	17226·5
5820·96	3	17174·2	5802·82	6	17228·9
5820·73	3	17175·9	5802·26	8	17229·6
5820·48	3	17175·6	5801·88	2	17230·7
5820·24	3	17176·3	5801·54	5	17231·7
5819·81	3	17177·6	5800·93	8	17233·5
5819·42	3	17178·7	5800·58	3	17234·6
5819·20	3	17179·4	5800·35	4	17235·2
5818·67	3	17181·0	5800·12	2	17235·9
5818·33	3	17182·0	5799·77	5	17237·0
5818·14	3	17182·5	5799·51	3	17237·7
5817·90 }	5 lines	17183·2	5799·23	4	17238·6
5817·07 }		17185·7	5798·75	4	17240·0
5816·26	4n	17188·1	5798·48	4	17240·8
5815·82*	3	17189·4	5798·15	7	17241·8
5815·52	2	17190·3	5797·77	2	17242·9
5815·14	4	17191·4	5797·30*	5b	17244·3
5814·76	3	17192·5	5796·81	7	17245·8
5814·34	4	17193·7	5796·43	4	17246·9
5814·12	2	17194·4	5796·19	3	17247·6
5813·77*	4	17195·4	5795·95	4	17248·3
5813·43	2	17196·4	5795·64	6	17249·2
5813·16	4	17197·2	5795·44	7	17249·8
5812·71	3	17198·6	5795·23	3	17250·5
5812·41	7n	17199·5	5794·94	4	17251·3

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5794·57	4	17252·4	5776·20	3	17307·3
5794·23	5	17253·4	5775·88	4	17308·3
5794·04	3	17254·0	5775·57	4	17309·2
5793·77	3	17254·8	5774·75	7	17311·7
5793·41	3⊙	17255·9	5774·43	3	17312·6
5793·13	3	17256·7	5773·90	7	17314·2
5792·92	4	17257·3	5773·36	4	17315·8
5792·74	4	17257·9	5773·02	6s	17316·9
5792·44	4	17258·8	5772·72	4	17317·8
5792·09	3	17259·8	5772·11	5s	17319·6
5791·65	4	17261·1	5771·59	4	17321·1
			5771·29	7	17322·0
			5770·86	3	17323·3
Group 5791–5763			5770·56	4	17324·2
			5770·19	4	17325·3
5791·04	3	17262·9	5769·89	4	17326·2
5790·81	4	17263·5	5769·65	3	17327·0
5790·46	4	17264·7	5769·40	2	17327·7
5790·19	3	17265·5	5769·06	4	17328·7
5789·77*	2	17266·7	5768·81	4	17329·5
5789·23	3	17268·3	5768·55	4	17330·3
5789·04	2	17269·9	5768·33	4	17330·9
5788·86	2	17269·5	5768·00	4	17331·9
5788·36	4	17270·9	5767·53	5	17333·3
5788·04	4	17271·9	5767·16	5	17334·4
5787·76	4	17272·7	5766·91	5	17335·2
5787·34	4	17274·0	5766·67	2	17335·9
5786·84	5	17275·5	5766·50	3	17336·4
5786·40	4bn	17276·8	5766·24	4	17337·2
5785·79	5	17278·6	5765·71	7	17338·8
5785·28*	4	17280·1	5765·03	6	17340·9
5784·82	3	17281·5	5764·42	8	17342·7
5784·65	3	17282·0	5764·13	3	17343·6
5784·13	?⊙	17283·6	5763·78	4	17349·6
5783·84	2	17284·4			
5783·54	4	17285·3			
5783·12	3	17286·6	Group 5763–5742		
5782·83	3	17287·5			
5782·46	6s	17288·6	5763·00	4	17347·0
5782·01	6s	17290·9	5762·70	5	17347·9
5781·64	2	17291·0	5762·23	4	17349·3
5781·46	3	17291·6	5761·94	4	17350·2
5781·13	3s	17292·2	5761·70	4	17350·9
5780·97	3	17293·0	5761·28	4n	17352·1
5780·64	3	17294·0	5760·83	4	17353·5
5780·38	4	17294·8	5760·33	6	17355·0
5780·19	3	17295·4	5759·88	3	17356·4
5779·76		17296·7	5759·64		17357·1
5779·43	4s	17297·6	5759·21	5 b	17358·4
5779·10	4s	17298·6	5758·89	5	17359·4
5778·74	4	17299·7	5758·56	4	17360·3
5778·47	3	17300·5	5758·21	4	17361·4
5778·21	4	17301·3	5757·71	5 b	17362·9
5777·73*	3	17302·7	5757·32	3	17364·1
5777·39	6	17303·7	5757·03	5	17365·0
5776·98	3	17305·0	5756·65	5	17366·1
5776·50	5	17306·4	5756·33	5	17367·1

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5756·01	3	17368·0	5738·11	7	17422·2
5755·80	3 b	17368·7	5737·89	2	17422·9
5755·56	2 b	17369·4	5737·60	2	17423·8
5755·36	3 b	17370·0	5737·25	6	17424·8
5755·14	3	17370·7	5736·81	4	17426·2
5754·59	3b	17372·3	5736·49*	7	17427·2
5754·26	5	17373·3	5736·14	2	17428·2
5753·91	5	17374·4	5735·92	2	17429·9
5753·12	3	17376·8	5735·70	4	17429·6
5752·84	3	17377·6	5735·45	4	17430·3
5752·58	4	17378·4	5735·18	3	17431·1
5752·35	3	17379·1	5734·97	4	17431·8
5751·83	4	17380·7	5734·71	4	17432·6
5751·49	3	17381·7	5734·26	4 b	17433·9
5751·30	2	17382·3	5733·97		17434·8
5751·00	2	17383·2	5733·57*	5 b	17436·0
5750·78	5	17383·8	5733·16*	3 b	17437·3
5750·49	3	17384·7	5732·82	4	17438·3
5750·27	3	17385·4	5732·62	3	17438·9
5749·69	5	17387·1	5732·44	3	17439·5
5749·43	4	17387·9	5732·19	5	17440·2
5749·20	4	17388·6	5731·56	5	17442·0
5748·89	2	17389·6	5731·28	2	17442·9
5748·57	7	17390·5	5730·97	8	17443·9
5747·55	7	17393·6	5730·28	5	17446·0
5747·19	2	17394·7	5729·69	8b	17447·7
5746·95	2	17395·4	5729·16	5	17449·4
5746·70	3	17396·2	5728·87	3	17450·2
5746·46	4s	17396·1	5728·56	5	17451·2
5746·10*	3	17398·0	5728·17	4	17452·4
5745·76*	3	17399·0	5727·87	3	17453·3
2745·45	4s	17400·0	5727·63	8b	17454·0
5745·23	3	17400·6	5726·98		17456·0
5744·85	4	17401·8	5726·71	5	17456·8
5744·46	8	17403·0	5726·45	2	17457·6
5744·11	2 b	17404·0	5726·14*	6	17458·6
5743·70	4 b	17405·3	5725·79	6	17459·6
5743·48	4s	17405·9	5725·54	6	17460·4
5743·24	2	17406·7	5725·07*	3	17461·8
5743·07	2	17407·2	5724·77	5	17461·7
5742·80	4s	17408·0	5724·43	5	17463·8
5742·54	6	17408·8	5724·13	4	17464·7
			5723·81	5	17465·6
			5723·52	4	17466·6
Group 5742–5712			5723·19*	3	17467·6
5741·89	4	17410·7	5722·80*	2	17468·8
5741·63	5	17411·5	5722·50	3	17469·7
5741·32	3	17412·5	5722·28	4	17470·3
5741·08	3	17413·2	5722·09	5	17470·9
5740·74	5	17414·3	5721·61	3	17472·4
5740·45	2	17415·1	5721·33	3s	17473·2
5739·81	8	17417·1	5721·12	3s	17473·9
5739·41	3	17418·3	5720·86	2	17474·6
5739·14	2	17419·1	5720·47	4	17475·8
5738·91	6	17419·8	5720·22	2	17476·5
5738·58	4	17420·8	5719·97	3	17477·4
5738·32	3	17421·6	5719·33	2b	17479·4

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5718·84	4	17480·8	5696·45	2	17549·6
5718·67	4	17481·3	5696·24	4	17550·2
5717·73	4	17484·3	5695·81	5	17551·6
5717·45	3	17485·1	5695·66	5	17552·0
5717·19	3	17485·9	5695·05	4b	17553·9
5717·02	4	17486·4	5694·73	2	17554·9
5716·75	2	17487·2	5694·48	4	17555·6
5716·59	4	17487·7	5694·25	2	17556·3
5716·39	2	17488·4	5693·89	6s	17557·5
5716·09	3	17489·3	5693·28	5	17559·4
5715·70	3	17490·5	5692·91	3	17560·5
5715·38	6⊙	17491·4	5692·58	4	17561·5
5714·94	3	17492·8	5692·24	2	17562·6
5714·49	5	17493·2	5691·94	5	17563·5
5714·20	2	17495·1	5691·57	4	17564·6
5713·64	5	17496·8	5691·31	3	17565·4
5713·35	4	17497·7	5691·10	3	17566·1
5713·00	2	17498·7	5690·70*	5⊙	17567·3
5712·73	2	17499·5	5690·38	2	17568·3
5712·44	6⊙	17500·4	5690·05	5	17569·3
5712·18	7⊙	17501·2	5689·68	4	17570·5
			5689·39	3	17571·4
Group 5712–5688			5689·14	2	17572·1
			5688·84	2	17573·0
5711·69	2	17502·7			
5711·38	6⊙	17503·6			
5710·42	5n	17506·6	Group 5688–5659		
5709·37	5	17509·8	5688·11	4	17575·3
5708·95	2	17511·1	5687·88	2	17576·0
5708·60*	5	17512·2	5687·60	2	17576·9
5708·40	2	17512·8	5687·27	4	17577·9
5707·94	2	17514·2	5686·96	4 } b	17578·9
5707·64	5	17515·1	5686·44	3 }	17580·5
5707·28	3	17516·3	5686·13	3	17581·4
5706·71*	4	17518·1	5686·76	4	17582·6
5705·79	5s⊙	17520·8	5685·45	2	17583·5
5705·35	3	17522·4	5685·14	2	17584·5
5704·97	4	17523·4	5684·82	4⊙	17585·5
5704·40	2	17525·1	5684·52	4⊙	17586·4
5704·12	4	17525·9	5683·98	2	17588·1
5703·94	4	17526·5	5683·68	3	17589·0
5703·33	5	17528·4	5683·99	4	17591·9
5702·86	2	17529·8	5682·38	4	17593·1
5702·53	7	17530·8	5681·93	2	17594·5
5701·83	6	17533·0	5681·64	2	17595·5
5701·05	5	17535·3	5681·26	4	17596·5
5700·79	2	17536·2	5680·90	2	17592·8
5790·49	4s	17537·1	5680·57	2	17593·9
5790·13	2	17538·3	5680·14	5	17605·2
5699·79	3	17539·3	5679·93	3	17605·8
5699·44	2	17540·3	5679·66	2	17601·5
5699·23	4	17541·0	5679·05	5	17603·4
5698·62	7	17543·0	5678·68	2	17604·5
5698·19	3	17544·2	5678·33	2	17605·6
5697·91	4	17545·1	5678·02	6	17606·6
5697·29	6	17547·0	5677·71	2	17607·5
5696·73	5	17548·7	5677·26	3	17608·9

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5676·93	6	17609·9	5656·10	2	17674·8
5676·31	4	17611·9	5655·80	4	17675·8
5676·00	4	17612·8	5655·39	4	17677·0
5675·39	4	17614·7	5654·80	3	17678·9
5645·06	4	17615·8	5654·44	3	17680·0
5674·81	3	17616·5	5654·14	4	17680·9
5674·52	2	17617·4	5653·60	3	17682·6
5674·06	3	17618·9	5653·16	4	17683·9
5673·78	3	17619·7	5652·91	4	17684·8
5673·45	3	17620·8	5652·56	4	17685·9
5673·14	3	17621·8	5651·91	4	17687·9
5672·73	4	17622·0	5651·68	2	17688·6
5672·46	2	17623·9	5651·39	2	17689·6
5672·20	3	17624·6	5651·04	4	17690·6
5671·96	5	17625·4	5650·76	5	17691·5
5671·65	2	17626·4	5650·00	3	17693·9
5671·22*	5	17627·7	5649·66	5	17695·0
5670·88	3	17628·8	5649·17	3	17696·5
5670·42	5	17630·2	5648·81	2	17697·6
5669·95	3	17631·7	5648·59	5	17698·3
5669·57	4	17632·8	5648·27	2	17699·3
5669·26	3	17633·8	5647·88	4	17700·6
5669·05	3	17634·4	5647·46	6	17701·9
5668·75	4	17635·4	5647·04	3	17703·2
5668·49	3	17636·2	5646·42	6	17705·1
5667·97	7	17638·8	5646·15	3	17705·9
5667·20	7	17640·2	5645·54	3	17707·9
5666·46	7	17642·5	5645·28	4	17708·7
5666·06	2	17643·7	5645·00	2	17709·6
5665·68	4	17645·9	5644·77	2	17710·3
5665·38	4	17646·9	5644·30	5⊙	17711·7
5664·89	5	17647·4	5643·58	3	17714·0
5664·63	3	17648·2	5643·20	4	17715·2
5664·31 }	6	17649·2	5642·84	3	17716·4
5664·06 }		17650·0	5642·57	3	17717·2
5663·52	6	17651·7	5642·17*	4	17718·5
5662·89	3	17653·7	5641·73	3⊙	17719·9
5662·59	4	17654·6	5641·28	3⊙	17721·3
5662·23	4	17655·7	5640·91	3	17722·4
5661·85	3	17656·9	5640·38	3	17724·1
5661·58	4	17657·7	5640·05	4	17725·1
5661·31 }	b (3 lines)	17658·5	5639·45	4	17727·0
5660·79 }		17660·2	5639·05	3	17728·3
5660·47	4	17661·2	5638·26 }	4	17730·8
5660·22	3	17662·0	5637·98 }		17731·6
5659·82	5	17663·2	5637·58*	5	17732·9
5659·37	6	17664·6	5637·14	2	17733·3
			5636·78	5s	17735·4
			5636·25	3	17737·1
Group 5659–5616			5635·95	4s	17738·0
5658·90	4	17666·1	5635·68	2	17738·9
5658·62	4	17667·0	5635·17	5	17740·5
5658·25	4	17668·1	5634·81	2	17741·6
5657·86	4	17669·3	5634·43	7	17743·8
5657·45	6	17670·6	5633·80	4	17744·8
5656·93	6	17672·2	5633·55	4	17745·6
5656·44	5	17673·7	5633·09	3	17746·6

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5632·78	5s	17748·0	5614·00	3	17807·3
5632·36*	4	17749·3	5613·51	4	17809·9
5632·02	5s	17750·4	5613·21	3	17809·8
5631·72	3	17751·4	5612·82	3	17811·0
5631·37	4s	17752·5	5612·46	4	17812·2
5631·13	4	17753·2	5612·19	4	17813·0
5630·87	2	17754·0	5611·83	2	17814·1
5630·63	5	17754·8	5611·48	3	17815·3
5630·30	2	17755·8	5611·21	3	17816·2
5630·00	4s	17756·8	5610·91	3	17817·1
5629·70	4s	17757·7	5610·74	3	17817·7
5629·39	4	17758·7	5610·46	3	17818·5
5628·96	2	17760·1	5610 22	3	17819·3
5628·69	4	17760·9	5609·94	3	17820·2
5628·41	2	17761·8	5609·69	3	17821·0
5628·14	4	17762·6	5609·33 }	3	17822·1
5627·88	2	17763·5	5608·86 }		17823·7
5627·49	5	17764·7	5608·54	2	17824·7
5626·96	5	17766·4	5608·22	4	17825·7
5626·43	4	17768·1	5607·95	4	17826·5
5626·13	2	17769·0	5607·63	3s	17827·5
5625·91 }	4	17769·7	5607·17	3s	17829·0
5625·72 }		17770·3	5606·72	3s	17830·4
5625·40	4	17771·3	5606·28*	3s	17831·8
5625·12	2	17772·2	5605·98	2	17832·8
5624·60	5 } †	17773·8	5605·70*	3s	17833·7
5624·29	4 }	17774·8	5605·21	4	17835·2
5624·00	4	17775·7	5604·79	5	17836·6
5623·60	3	17777·0	5604·39	3	17837·9
5623·40	3	17777·6	5604·11	5	17838·7
5623·19	3	17778·3	5603·27	6	17841·4
5622·90	3	17779·2	5602·84	3	17842·8
5622·48	4	17780·5	5602·44	6	17844·1
5622·16	3	17781·5	5601·90	3	17845·8
5621·90	4	17782·3	5601·60	5⊙	17846·7
5621·49	3	17783·6	5601·29	4	17847·7
5621·24	2	17784·5	5600·89	5	17849·0
5621·03	4	17785·0	5600·56	4	17850·0
5620·83	3	17785·6	5600·26	2	17851·0
5620·59	2	17786·4	5600·04	5	17851·7
5620·35	2	17787·2	5599·60	2	17853·1
5620·00	5	17788·3	5599·33	4	17854·0
5619·65	5	17789·4	5598·70*	6⊙	17856·0
5619·23	4	17790·7	5598·18	4 }	17857·6
5618·70	4	17792·4	5597·90 } b		17858·5
5618·29	2	17793·7	5597·42 }		17860·1
5617·61	6	17795·9	5597·14	4	17861·0
5617·06	3	17797·6	5596·94	5	17861·6
5616·68	4	17798·8	5596·57	6	17863·8
5616·27	2	17800·1	5596·17	6	17864·1
			5595·69	7	17865·6
Group 5616–5587			5595·17	6	17867·3
			5594·47	5	17869·5
5615·38	4	17803·0	5594·00	5	17871 0
5614·85	2	17804·6	5593·65	5	17872·1
5614·54	3	17805·6	5593·17	4	17873·7
5614·29	3	17806·4	5592·68	8	17875·2

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5592·24	4	17876·6	5572·73	6	17939·2
5591·90	4	17877·7	5572·21	4	17940·9
5591·56	4	17878·8	5571·95	3	17941·8
5591·10	5s	17880·3	5571·72	2	17942·5
5590·71	5	17881·5	5571·49	4	17943·2
5590·38	4⊙	17882·6	5571·16	3	17944·3
5590·16	4	17883·3	5570·90	4	17945·1
5589·84	4	17884·3	5570·67	2	17945·9
5589·49*	5	17885·4	5570·47		17946·5
5589·05	4	17886·6	5569·90	6b	17948·4
5588·63	3	17888·2	5569·56		17949·5
5588·40	3	17888·9	5569·16*	5	17950·7
5588·16	3	17889·7	5568·83	3	17951·8
5587·83	3	17890·8	5568·41	5	17953·2
5587·54	3	17891·7	5568·11	5	17954·1
5587·31	4	17892·4	5567·57	4⊙	17955·9
			5567·36	4	17956·5
Group 5587–5555			5567·08	3	17957·4
			5566·75	6	17958·5
5586·74	2	17894·3	5566·33		17959·9
5586·46	2	17895·1	5565·97	7	17961·1
5586·15	5	17896·1	5565·52	5	17962·5
5585·81	5	17897·2	5565·26	3	17963·3
5585·48	2	17898·3	5565·00	3	17964·1
5585·09	4	17899·5	5564·70	5	17965·1
5584·67	3	17900·9	5564·33	4	17966·3
5584·41	2	17901·7	5563·90	6⊙	17967·7
5584·00	4	17903·0	5563·49	4	17969·0
5583·64	3	17904·2	5563·00	7⊙	17970·6
5583·31	3	17905·2	5562·44	5	17972·5
5582·94	5	17906·4	5562·20	2	17973·2
5582·62	3	17907·4	5561·97	3	17974·0
5581·90	4	17909·8	5561·75	5	17974·7
5581·63	4	17910·6	5561·35	6	17975·9
5581·39	4	17911·4	5561·00	4	17977·1
5581·00	2	17912·6	5560·72	3	17978·0
5580·70	4	17913·6	5560·44	7	17978·9
5580·39	2	17914·6	5560·16	6	17979·8
5580·08	3	17915·6	5559·86	6	17980·8
5579·60*	4 b	17917·1	5559·53*	5	17981·9
5579·25	2	17918·3	5559·20	2	17982·9
5578·65	4	17920·2	5558·82	4	17984·2
5578·30	2	17921·3	5558·53	3	17985·1
5578·07	2	17922·0	5558·05	4	17986·6
5577·79	3	17923·0	5557·42	8	17988·7
5577·47	3	17924·0	5556·93	8	17990·3
5577·18	2	17924·9	5556·39	8	17992·0
5576·93	3	17925·7	5556·03	6	17993·1
5576·74	2	17926·3	5555·86	6	17993·8
5575·99	4	17928·8	5555·55	3	17994·8
5575·49	4	17930·4			
5575·19	2	17931·3			
5574·89	3	17932·3	Group 5555–5528		
5574·57	4s	17933·3	5555·02	2	17996·4
5574·32	3	17934·1	5554·82	3	17997·1
5573·63	7	17936·3	5554·50	3	17998·1
5572·93	6	17938·6	5554·14	4	17999·3

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5553·86	4⊙	18000·2	5536·19	3	18057·7
5553·53*	4	18001·3	5535·88	4	18058·7
5553·09*	4	18002·7	5535·47*	4	18060·0
5552·65	4	18004·1	5535·04*	5	18061·4
5552·39	2	18005·0	5534·72	2	18062·4
5552·22	4	18005·5	5534·50	5	18063·2
5551·94	3	18006·4	5534·31	5	18063·8
5551·72	4	18007·1	5533·86	5	18065·3
5551·23	4	18008·7	5533·67	2	18065·9
5550·83	4	18010·0	5533·43*	3	18066·7
5550·47	4	18011·2	5533·06	4⊙	18067·9
5550·25	4	18011·9	5532·76	4	18068·8
5549·87	5	18013·1	5532·46	2	18069·8
5549·62	2	18014·0	5532·24	4	18070·6
5549·47	2	18014·5	5532·00	2	18071·3
5549·32	3	18014·9	5531·68	4	18072·4
5548·95	5s	18016·1	5531·40	4	18073·3
5548·72	3	18016·9	5531·15	5	18074·1
5548·45	3	18017·8	5530·65	6	18075·7
5548·14*	4	18018·8	5530·37	2	18076·7
5547·81	2	18019·8	5530·08	5	18077·6
5547·54	4s	18020·7	5529·44	5	18079·7
5547·36	2	18021·3	5529·20	2	18080·5
5547·14*	4	18022·0	5529·02	2	18081·1
5546·64	4	18023·6			
5546·33	4	18024·6	Group 5528–5502		
5546·06	3	18025·5			
5545·81	4	18026·3	5528·39	3	18083·1
5545·46	4	18027·5	5528·10	2	18084·1
5545·11*	2	18028·6	5527·87	4	18084·8
5544·78*	5	18029·7	5527·61	4	18085·7
5544·45	2	18030·8	5527·34	2	18086·6
5543·97	5	18032·3	5526·82	3	18088·3
5543·71	2	18033·2	5526·55	4	18089·2
5543·44	5s⊙	18034·0	5526·35		18089·8
5543·16		18034·9	5526·05	2	18090·8
5542·74	5	18035·3	5525·80	3⊙	18091·6
5542·34	3	18037·6	5525·53	2	18092·5
5542·08	6	18038·5	5525·30	3	18093·3
5541·71	2	18039·7	5525·04	3	18094·1
5541·52	2	18040·3	5524·85	3	18094·8
5541·20	5	18041·3	5524·62	3	18095·5
5540·99	5	18042·0	5524·32	3	18096·5
5540·72	3	18042·9	5524·10	3	18097·2
5540·28	4s b	18044·3	5523·84	3 b	18098·0
5539·94		18045·5	5523·63	2	18098·7
5539·58	4	18046·6	5523·38	2	18099·5
5539·29	5s	18047·6	5522·98	4s	18100·9
5538·98	2	18048·6	5522·45	2	18102·6
5538·78	4⊙	18049·2	5522·10	5	18103·7
5538·43	4	18050·4	5521·78	3	18104·8
5537·83		18052·3	5521·15	4	18106·8
5537·50	4	18053·4	5520·73	4s	18107·1
5537·24	3	18054·2	5520·53	2	18108·8
5536·92	4	18055·3	5520·32	4s	18109·5
5536·70	3	18056·0	5520·04	3	18110·4
5536·43	2	18056·9	5519·80	3	18111·2

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5519·40	3	18112·5	5499·50	4	18188·1
5518·95	4	18114·0	5499·21	3	18189·0
5518·63	3	18115·0	5499·05	2	18189·6
5518·23	3	18116·4	5498·85	3	18190·2
5518·03	3	18117·0	5498·60	6	18191·1
5517·58	2	18118·5	5498·23	3	18192·3
5517·33	2	18119·3	5497·60	2	18194·3
5517·03	5	18120·6	5497·32	4	18195·3
5516·67	4	18121·7	5497·00	2	18196·3
5516·22	5	18123·0	5496·75	2	18197·2
5515·89	5	18124·0	5496·41	6s	18198·3
5515·49	3	18125·4	5496·01	5	18199·6
5515·17	3	18136·4	5495·53	5	18201·2
5514·91 }	4⊙	{ 18137·3	5495·25	2	18202·1
5514·70 }		{ 18137·9	5494·95	5	18203·1
5514·14	3	18139·8	5494·69	2	18204·0
5513·73	3	18141·1	5494·47	2	18205·7
5513·48	2	18142·0	5494·12	5	18205·9
5513·13	5	18143·1	5493·78	5	18207·0
5512·82	5	18144·1	5493·55	5	18207·8
5512·43	4	18145·4	5493·28	4s	18208·7
5512·15	4	18146·3	5492·98	4	18209·7
5511·65	4*	18148·0	5491·98 }	7	18213·0
5511·29	5	18149·2	5491·36 }		18215·0
5511·03	4	18150·0	5490·97	5	18216·3
5510·69	2	18151·1	5490·66	4	18207·4
5510·35	4	18152·3	5490·34	5	18208·4
5509·87	4	18153·8	5489·92	4	18209·8
5509·62	3	18154·7	5489·67	2	18210·6
5509·39	4	18155·4	5489·42	4	18211·5
5509·12	4	18156·3	5489·13	4	18212·4
5508·84	4	18157·2	5488·77	3s	18213·6
5508·67	3	18157·8	5488·42	5	18214·8
5508·45	3	18158·5	5487·88	2	18216·6
5508·21	3	18159·3	5487·53	4	18217·8
5507·91	5s	18160·3	5487·22	3	18218·8
5507·59	4*	18161·4	5486·87	4	18219·9
5506·88 }	7	18163·7	5486·65	2	18220·7
5506·36 }		18165·4	5486·46	2	18221·3
5505·98	2	18166·7	5486·22	2	18222·1
5505·75	5	18167·4	5486·04	4	18222·7
5505·40	4	18168·6	5485·73	4	18223·7
5505·11	4*	18169·5	5485·45	3	18224·6
5504·72	6*	18170·8	5485·19 }	6	18225·5
5504·31	5*	18172·2	5484·93 }		18226·4
5503·90	2	18173·5	5484·54	5	18227·7
5503·62	6	18174·4	5483·92	5	18229·7
5503·23	3	18175·7	5483·70	4	18230·5
5502·13	5s	18179·4	5483·35	3	18231·6
			5483·01	3	18232·7
			5482·70 }	6	18233·8
Group 5502–5477			5482·53 }		18234·4
5501·46	4	18181·6	5482·17	6*	18235·6
5501·13	5	18182·7	5481·41	5	18238·1
5500·58	6	18184·5	5481·11	5	18239·1
5500·34	3	18185·3	5480·78	3	18240·2
5499·97	4	18186·5	5480·52	3	18241·1

BROMINE (ABSORPTION)—*continued.*

Wave-length	Character and Intensity	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5480·25	5	18242·0	5462·87	5	18300·0
5479·89	3	18243·2	5462·58	5	18301·0
5479·32	6	18245·0	5462·31	4	18301·9
5478·96	8	18246·3	5461·81	7	18303·5
5478·48	3	18247·9	5461·42	5	18304·8
5478·18	3	18248·9	5461·20	5	18305·6
5477·89	3	18249·8	5460·74	6	18307·2
5477·65	2	18250·6	5460·19	7	18309·0
5477·15	4	18252·3	5459·67	4*	18310·7
			5459·19	5	18312·3
			5458·79	3	18313·7
Group 5477–5456			5458·60	3	18314·3
5476·42	4	18254·7	5458·29	2	18315·4
5476·10	4	18255·8	5457·97	5	18316·4
5475·91	4	18256·4	5457·53	3	18317·9
5475·69	2	18257·1	5457·15	7	18319·2
5475·23	5	18258·7	5456·89	7	18320·1
5474·91	4	18259·7	5456·54	3	18321·2
5474·62	4	18260·7	5456·27	2	18322·1
5474·24	4⊙	18261·0	5456·03	4	18322·9
5473·90	4	18263·1			
5473·67	4	18263·9	Group 5456–5430		
5473·48	4	18264·5	5455·62	6	18324·3
5473·26	3	18265·2	5455·28	2	18325·5
5472·98	5	18266·2	5455·08	5	18326·1
5472·69	4	18267·1	5454·84	5	18327·0
5472·33	3	18268·3	5454·64	3	18327·6
5472·04	5s	18269·3	5454·12	4	18329·4
5471·73	3	18270·3	5453·84	4	18330·3
5471·43	5	18271·3	5453·10	4*	18332·8
5470·99	3⊙	18272·8	5452·76	5s	18333·9
5470·76	3	18273·6	5452·50	3	18334·8
5470·39	5*	18274·8	5452·23	4	18335·7
5470·04	4	18276·0	5451·85	5	18337·0
5469·72	4	18277·1	5451·34	5	18338·7
5469·45	4	18278·0	5451·05	4	18339·7
5468·94	6	18279·7	5450·87	4	18340·3
5468·68	2	18280·5	5450·63	2	18341·1
5468·49	2	18281·2	5450·42	2	18341·8
5468·32	2	18281·7	5449·94	4	18343·4
5468·13	3	18282·4	5449·69 }	4	18344·3
5467·90	2	18283·1	5449·13 }		18346·2
5467·65	2	18284·0	5448·83	2	18347·2
5467·24	6	18285·4	5448·57	3	18348·1
5466·84 }		18286·7	5448·15	3	18349·4
5466·71 }	8⊙?	18287·1	5447·75	3	18350·8
5466·29 }		18288·4	5447·50	2	18351·6
5465·87	5	18289·9	5447·31	5	18352·3
5465·59	3	18290·9	5446·52	4	18354·9
5465·29	2	18291·9	5446·26	2	18355·8
5464·96	6	18293·0	5446·09	3	18356·4
5464·62	3	18294·1	5445·86	3	18357·2
5464·46	3	18294·7	5445·49	2	18358·4
5464·25	3s	18295·4	5444·89	3 } b	18360·5
5464·05	2	18296·0	5444·65	2 }	18361·3
5463·84	2	18296·8	5444·43 }	5	18362·0
5463·17	4	18299·0	5444·16 }		18362·9

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5443·75	3	18364·3	5426·66	3	18422·1
5443·48	5	18365·2	5426·38	4	18423·1
5443·15	2	18366·3	5423·03	3	18424·3
5442·86	6	18367·3	5425·85	3	18424·9
5442·52	3	18368·4	5425·55	5	18425·9
5442·21	4	18369·5	5425·00	5	18427·8
5441·95	4	18370·4	5424·59	3	18429·2
5441·77	?	18371·0	5424·27	5	18430·3
5441·32	5 b	18372·5	5423·90	2	18431·3
5440·87*	4	18374·0	5423·53*	5	18432·8
5440·65	4	18374·7	5423·06	4	18434·4
5440·24	4	18376·1	5422·64	4	18435·8
5439·75	6	18377·8	5422·22	5	18437·2
5439·53	2	18378·6	5421·88	5	18438·4
5439·31	2	18379·3	5421·53	2	18439·6
5439·05	5	18380·2	5421·25	4	18440·4
5438·74	3	18381·2	5420·98	3	18441·4
5438·46	5	18382·2	5420·61	6	18442·7
5438·15	2	18383·2	5420·16	2	18444·2
5437·90	4	18384·0	5419·87	4	18455·2
5437·53	4	18385·3	5419·62	2	18456·1
5437·32	4	18386·0	5419·31	5s	18457·1
5436·98		18387·2	5418·99	4s	18458·2
5436·74	8	18388 0	5418·23	6*	18460·8
5436·39		18389·2	5417·87	2	18462·0
5436·12	3⊙	18390·1	5417·50	6	18463·2
5435·90	2	18390·8	5417·03	7	18464·8
5435·61	3	18391·8	5416·82	2	18465·5
5435·31	5	18392·8	5416·60	4	18465·3
5435·09	2	18393·6	5416·31	4	18467·3
5434·55	2⊙?	18395·4	5415·96	6	18468·4
5434·28	4	18396·3	5415·56		18469·8
5433·98	2	18396·4	5415·15	4	18471·2
5433·71	4	18398·3	5414·76	6	18472·5
5433·26	5	18399·8	5414·35	4	18473·9
5432·81	3	18401·3	5413·91	7	18474·4
5432·25	7	18403·2	5413·63	4	18475·4
5431·95	2	18404·2	5413·48	4	18476·9
5431·56	3	18405·5	5413·08	3	18478·3
5431·24	4	18406·6	5412·89	5	18178·9
5431·03	2	18407·3	5412·46	3	18480·4
5430·60	4	18409·8	5412·23	3	18481·2
5430·24	5	18410·0	5411·89	5	18482·3
			5411·62	2 ⊙?	18483·2
			5410·93	6	18485·6
Group 5430–5406			5410·64	2	18486·6
5429·73	4	18411·7	5410·32	2	18487·7
5429·43	4	18412·7	5409·88	4	18489·2
5429·22	4	18413·4	5409·46	3	18490·6
5428·77	4	18415·0	5409·19	4	18491·6
5428·46	3	18416·0	5408·91	6	18492·5
5428·22	4	18416·8	5408·42	3	18493·2
5428·00	3	18417·6	5408·10	5	18494·3
5427·82	3	18418·2	5407·86	3	18496·1
5427·54	3	18419·1	5407·58	4	18497·1
5427·25	4	18420·1	5407·23	4	18498·2
5426·90	3	18421·3	5407·03	3	18498·9

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5406·80	2	18499·7	5386·59	3	18559·1
5406·58	2	18500·5	5386·10		18560·8
5406·33	2	18501·3	5385·81	3	18561·8
			5385·58	3	18562·6
			5385·22		18563·8
Group 5406–5372			5384·93	4	18564·9
			5384·55	5	18565·2
5405·52	4	18504·1	5384·14	5	18567·6
5405·18	4	18505·2	5383·46	3	18569·8
5404·76	3	18506·7	5383·24	2	18570·7
5403·89	4	18499·7	5382·98	3	18571·6
5403·16	4	18502·2	5382·78	3	18572·3
5402·38	5	18504·0	5382·52	3	18573·2
5402·08	3	18504·9	5382·25	4	18574·1
5401·67		18507·3	5382·00	2	18574·9
5401·33	3	18508·5	5381·71	2	18576·0
5401·00	4	18509·6	5381·37*	5⊙	18577·2
5400·25	4	18512·2	5381·05	2	18578·2
5499·68	5	18514·1	5380·71*	4b	18579·4
5499·39	2	18515·1	5380·21	4	18581·1
5499·09	2	18516·1	5379·65	5	18583·1
5498·84	2	18517·0	5378·79	4	18586·1
5498·55	5	18518·0	5378·50	3	18587·1
5497·89	3	18520·3	5377·93	6	18589·0
5497·37	4⊙	18522·0	5377·56	4	18590·3
5496·90	5	18523·6	5377·33	3	18591·1
5396·54	3	18524·9	5377·02	4	18592·2
5396·33	3	18525·6	5376·74	3	18593·1
5395·95	3	18526·9	5376·26	2n	18594·8
5395·73	3	18527·7	5375·92	7	18596·0
5395·46	3	18528·6	5375·39	3	18598·8
5395·24	2	18529·4	5375·12	3	18598·7
5395·01	3	18530·1	5374·84	3	18599·7
5394·66	4b	18531·3	5374·49	2	18600·9
5394·18	4	18533·0	5374·25	3	18601·7
5393·91	2	18533·9	5373·74	3	18603·5
5393·66	4	18534·8	5373·57	3	18604·1
5393·23	2	18536·3	5373·01	4	18606·1
5392·74	4	18538·0	5372·65	2	18607·3
5392·52	2	18538·7	5372·30	6	18608·5
5392·29	2	18539·5	5372·11	6	18609·2
5392·05	3	18540·3			
5391·77	4⊙	18541·3			
5391·47	2	18542·3	Group 5372–5354		
5391·16	3	18543·4	5371·31	3	18611·9
5390·90	6	18544·3	5371·01	3	18613·0
5390·48	2	18545·7	5370·60*	3*	18614·4
5389·92*	6	18547·7	5369·93	5n	18616·7
5389·57	2	18548·9	5369·44	5	18618·4
5389·31	2	18549·8	5369·00	3	18619·9
5388·93	4	18551·1	5368·61*	4*	18621·3
5388·61	3	18552·2	5368·18	3	18622·8
5388·15	4	18553·7	5367·45	3	18625·3
5387·72	3	18555·3	5367·21		18626·1
5387·49	3	18556·0	5366·47	3	18628·7
5387·22	3	18557·0	5366·16	2	18629·8
5386·92	2	18558·0	5365·64	5⊙	18631·6

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5365·39	3	18632·5	5345·02	2	18703·4
5364·82	3	18634·4	5344·72	3	18704·4
5364·27	5	18636·4	5344·45	4	18705·4
5364·00	4	18637·3	5344·09	4	18706·6
5363·44	4	18639·2	5343·76	5s⊙	18707·8
5363·20	4	18640·1	5343·41	4	18708·0
5362·85	3	18641·3	5343·12	5	18709·1
5362·36	4	18643·0	5342·80	4	18711·2
5361·92*	4	18644·5	5342·38	6	18712·6
5361·62	2	18645·6	5341·82	6	18714·6
5361·37	4	18646·4	5340·92	6	18717·8
5361·07	4	18647·6	5340·56	3	18719·0
5360·69	3	18648·8	5340·01	4	18721·0
5360·33	3	18650·1	5339·65	4	18722·2
5360·00	4	18651·2	5339·24	4	18723·7
5359·73	3	18652·2	5338·85	3	18724·0
5359·46	3	18653·1	5338·60	2	18725·9
5359·22	3	18653·9	5338·31 }	7	18726·9
5358·95	3	18654·9	5338·07 }		18727·8
5358·69	2	18655·7	5337·76	2	18728·8
5358·35	5	18656·9	5337·46	4s	18729·9
5357·92	4	18657·4	5336·83	2	18732·1
5357·64	2	18658·3	5336·53	4	18733·2
5357·38	4	18660·2	5336·23	2	18734·2
5357·06	3	18660·3	5335·91	2	18735·3
5356·49	7	18662·3	5335·60	4	18736·4
5355·62	5	18666·4	5334·91 }	4	18738·9
5355·24	3	18667·7	5334·70 }		18739·6
5355·01	3	18668·5	5334·23 }	5	18741·2
5354·71	3s	18669·5	5333·94 }		18742·3
5353·80	7	18672·7	5333·49	3	18743·8
			5333·11	6	18745·2
Group 5354–5333					
5353·25	2	18674·6	Group 5333–5317		
5353·00	4	18675·5			
5352·62	3	18676·8	5332·80	3	18746·3
5352·21	3	18678·3	5332·56	2	18747·1
5351·64	2	18680·3	5332·28	3	18748·1
5351·44	4	18681·0	5332·07	3	18748·8
5351·19	3	18681·8	5331·79	3	18749·8
5350·86	3	18683·0	5331·55	3	18750·7
5350·65	2	18683·7	5331·30	4	18751·5
5350·37	4	18684·7	5331·02	2	18752·5
5350·15	5	18685·5	5330·74	5	18753·5
5349·74	5	18686·9	5330·44	5	18754·6
5349·06	4	18689·3	5330·06	5	18755·9
5348·35	2	18691·7	5329·60 } †	8	18757·5
5348·06	6	18692·8	5329·30 }		18758·6
5347·87		18693·4	5328·09*	5	18762·8
5347·48	4	18694·8	5327·81	2	18763·8
5346·93	3	18696·7	5327·34	5	18765·5
5346·66	4	18697·7	5327·00	5	18766·7
5346·42	3	18698·5	5326·67	4	18767·8
5346·07	3	18699·7	5326·40†	3 }	18768·8
5345·80	4	18700·7	5326·10	}	18769·9
5345·41	5	18702·0	5325·86	4	18770·7

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5325·61 } †	3	18771·6	5308·18	2	18833·2
5325·24 }		18772·9	5307·77	5	18834·7
5325·03	4	18773·6	5307·27	5	18836·5
5324·72	4	18774·7	5306·92	2	18837·7
5323·98	4	18776·3	5306·65	4	18838·7
5323·76 }	5	18777·1	5306·30 }	5	18839·9
5323·40 }		18779·4	5306·12 }		18840·6
5323·07	4	18780·5	5305·86	2	18841·5
5322·61	4	18782·2	5305·59	4	18842·4
5322·26	3	18783·4	5305 22	4	18843·8
5321·84	2	18784·9	5305·09	3	18844·2
5321·53*	3*	18785·0	5304·90	2	18844·9
5321·15	4	18786·3	5304·55	4	18845·1
5320·81	3	18788·5	5304·34	2	18846·9
5320·55	3	18789·4	5304·06	5	18847·9
5320·27	4	18790·4	5303·68	3	18849·2
5319·77 }		18792·2	5303·50	2	18849·9
5319·56 }	6	18792·9	5303·25	3	18850·8
5319·11 }		18794·5	5303·05	3	18851·5
5318·66	4	18796·1	5302·86	3	18852·1
5318·40	3	18797·0	5302·15	3	18854·7
5318·09*	3	18798·1	5301·83	4	18855·8
5317·70	5	18799·5	5301·57	2	18856·7
5317·40	2	18800·6	5301·08*		18858·5
5317·16	4	18801·4	5300·74	3	18859·7
			5300·57	3	18869·3
			5300·20	3s	18861·6
Group 5317–5289			5299·81	3b	18863·0
			5299·43	3	18864·3
5316·90	4	18802·3	5298·35	4⊙	18868·2
5316·47	2	18803·9	5298·06	3	18869·2
5316·09	4 b*?	18805·2	5297·48	]	18871·3
5315·85	2	18806·1	5296·48	4 }	18874·9
5315·60	2	18807·0	5296·15 }	5	18876·0
5315·30 }	4	18808·0	5295·73 }	†	18877·5
5315·08 }		18808·8	5295·29	3	18879·1
5314·83	2	18809·7	5295·04	3	18880·0
5314·55 }	5	18810·7	5294·77	3	18881·0
5314·30 }		18811·6	5294·32	4	18882·6
5313·85	3	18813·1	5293·94	4	18883·9
5313·46	4	18814·5	5293·56	5	18885·3
5313·09	3s	18815·8	5293·27	3	18886·3
5312·67	3	18816·3	5292·94	3	18887·5
5312·42	2	18818·2	5292·72	3	18888·3
5312·19	2	18819·0	5292·42	2	18889·3
5311·91	4	18820·0	5292·06	5	18890·6
5311·66	2	18820·9	5291·78	2	18891·6
5311·17	4	18822·6	5291·49	4	18892·7
5310·91	4	18823·6	5291·30	4	18893·3
5310·69	2	18823·3	5291·02	3	18894·3
5310·43	4	18824·3	5290·78	3	18895·2
5310·17 } b		18826·2	5290·47 }	6	18896·3
5309·71 }	5	18827·8	5290·21 }		18897·2
5309·34	3	18829·1	5289·93 }	*	18898·2
5309·11	3	18829·9	5289·53	4	18899·7
5308·86	3	18830·8	5289·19	2	18900·9
5308·46	4	18832·2	5288·85	5	18902·1

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
Group 5289–5262		
5288·63	3	18902·9
5288·33	2	18904·0
5288·07	2	18904·9
5287·76	4	18906·0
5287·51	2	18906·9
5287·30	3s	18907·6
5287·03	3s	18908·6
5286·74	3*?	18909·6
5286·36	5	18911·0
5285·91	3	18912·6
5285·49	4⊙	18914·1
5285·11*	4	18915·5
5284·73	4	18916·8
5284·44	3⊙	18917·9
5283·75	3	18920·4
5283·44	2	18921·5
5283·08	4	18922·7
5282·83	3	18923·6
5282·53	2	18924·7
5281·97	2	18926·7
5281·77	2	18927·4
5281·50	2	18928·4
5281·07	4	18930·0
5280·74	3⊙	18931·1
5280·26	4	18932·9
5279·89	2	18934·2
5279·44	4	18935·8
5279·12	3	18936·9
5278·67	4	18938·6
5278·31	2	18939·9
5277·96	3	18941·1
5277·71	3	18942·0
5277·47	3	18942·9
5277·23	3	18943·7
5277·00	3	18944·6
5276·67	2	18945·7
5276·19	4	18947·5
5275·62	5⊙	18949·5
5274·81	3	18952·4
5274·34	4	18954·1
5274·02	4	18954·3
5273·73	5⊙	18956·3
5273·04*	5	18958·8
5272·68 } †	5	18959·1
5272·29 } †		18961·5
5271·95	4	18962·7
5271·72	3	18963·5
5271·51	2	18964·3
5271·26	4	18965·2
5271·09	2	18965·8
5270·34*	2	18968·5
5269·43	4n	18971·8
5268·92	4	18973·6
5268·59	4	18974·8
5268·06	2	18976·7
5267·74	4	18977·9
5267·36	4	18978·2
5266·64	4	18981·8
5266·03*	3⊙	18984·0
5265·73	2	18985·1
5265·48	3	18986·0
5265·20	3	18987·0
5264·86	2	18988·2
5264·29	4	18990·3
5263·98	2	18991·4
5263·55	4	18993·0
5263·21	3	18994·2
5263·02	3	18995·9
5262·37	2	18997·2
Group 5262–5213		
5261·81	2	18999·3
5261·59	2	19000·1
5261·37	3	19000·8
5261·17	4	19001·6
5260·96	3 } b	19001·3
5260·40	4 } b	19004·4
5260·10	3	19005·4
5259·87	3	19006·3
5259·54	5	19007·5
5259·22	3 } Min.	19008·6
5258·87*	5 } Min.	19009·9
5258·54	2	19011·1
5258·32	3	19011·9
5258·10	4	19012·7
5257·83	4	19013·6
5257·43	4	19015·1
5257·09	3	19016·3
5256·82	3	19017·3
5256·32	6	19019·1
5255·79	6	19021·0
5255·06	2	19023·7
5254·74	5	19024·8
5254·30	4	19026·4
5254·03	2	19027·4
5253·77	5⊙	19028·3
5253·33	5	19029·9
5253·01	2	19031·1
5252·75	3	19032·0
5252·50	4	19032·9
5251·87	6	19035·2
5251·48	5	19036·6
5251·24	5	19037·5
5250·33	4	19040·8
5250·06	4	19041·8
5249·73	6	19043·0
5249·41	4	19044·2
5248·80	6 } Min.	19046·4
5248·30*	5 } Min.	19048·2
5247·61	6	19050·7
5247·34	5⊙	19051·7

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5247·03	2	19052·8	5226·65	4	19127·0
5246·76	4	19053·8	5226·38	3	19128·0
5246·45	3	19054·9	5226·18	3	19128·7
5246·18	3	19055·9	5225·87	5⊙	19129·9
5245·83*	4	19057·2	5225·45 }	5	19131·4
5245·33	6	19059·0	5224·61 }		19134·5
5245·01 }		19060·1	5224·23	4	19135·9
5244·60 }	4 †	19061·6	5223·97	4	19136·8
5244·33 }	3	19062·6	5223·75	2	19137·6
5243·47 }	3 †	19065·7	5223·44	5	19138·8
5242·66	3	19068·7	5223·02	5	19140·3
5242·37	5	19069·7	5222·32	5	19142·9
5241·88	6	19061·5	5222·04	3	19143·9
			5221·82	5	19144·7
Group 5243–5215			5221·47	4	19146·0
			5221·05*	4	19147·5
5241·72	6	19072·0	5220·69	5	19148·9
5241·48	3	19072·9	5220·34	3	19150·1
5241·34	3	19073·4	5220·07	3	19151·1
5241·12	2	19074·2	5219·60*	5	19152·9
5240·75	5	19075·5	5219·28	4	19154·0
5240·44	2	19076·7	5218·03	2	19158·6
5240·15	5⊙	19077·7	5217·54	3	19160·4
5239·87	2	19078·7	5217·23	3	19161·6
5239·69	3	19079·4	5216·95	4	19162·6
5239·45	4	19080·3	5216·45	2	19164·4
5239·23	4	19081·1	5216·19	2	19165·4
5239·00	3	19981·9	5215·92	7	19166·4
5238·77		19082·7			
5238·47		19083·8			
5238·21 }		19084·8	Group 5215–5202		
5238·00 }		19085·6	5214·85	3	19170·3
5237·66*	⊙	19086·8	5214·53	3	19171·5
5237·37		19087·8	5214·23	3	19172·6
5236·88		19089·6	5213·98	3	19173·5
5236·07		19092·6	5213·59	2	19174·9
5235·70	⊙	19093·9	5213·31	3	19176·0
5235·19	4	19095·8	5213·07	3	19176·8
5234·69	3	19097·6	5212·82	2	19177·8
5234·43	3	19098·6	5212·47	2	19179·1
5234·00	6	19099·1	5212·14	4	19180·3
5233·62	5	19101·5	5211·83	5	19181·4
5232·82	5	19104·6	5211·56	2	19182·4
5232·50	4	19105·6	5211·30	2	19183·4
5232·18*	5	19106·8	5211·00	3	19184·5
5231·91 }	4 4 Lines	{ 19107·8	5210·40	4	19186·7
5231·39 }		{ 19109·7	5210·08	3	19187·9
5231·16	3	19110·5	5209·75	3	19189·1
5230·93	3	19111·4	5209·41	4	19190·3
5230·71	3	19112·2	5208·39	2	19194·1
5230·47	4	19113·0	5207·80	4	19196·3
5229·68	4	19115·9	5207·39	2	19197·8
5229·40	4	19117·0	5207·21	2	19198·4
5229·04	4	19118·3	5206·96	2	19199·4
5228·54	2	19120·1	5205·77	2	19203·8
5228·28	4	19121·0	5205·54	2	19204·6
5227·98	4	19122·1	5205·28	4s	19205·6

BROMINE (ABSORPTION)—*continued.*

Wave-length	Intensity and Character	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Oscillation Frequency in Vacuo
5204·52	3s	19208·4	Group 5184–5159		
5203·96	3	19210·4	5183·60	6	19285·9
5203·73 }	4b	19211·3	5183·25	2	19287·2
5203·33 }		19212·8	5183·06	3	19287·9
5203·04	3 } b	19213·8	5182·72	4n	19289·2
5202·33	3 }	19216·5	5182·27	4n	19290·9
			5181·83	4n	19292·5
			5181·62	3n	19293·3
Group 5202–5184			5181·34	3	19294·3
			5180·82	5	19296·3
5202·07	3	19217·4	5180·39	4	19297·9
5201·77	2	19218·5	5180·03	4	19299·2
5201·44	4	19219·7	5179·68	4 } b	19300·5
5201·00*	3	19221·4	5179·26	2 }	19302·1
5200·72 }	4n	19222·4	5178·56	7	19304·7
5200·44 }		19223·4	5178·28	3	19305·7
5200·18 }	4	19224·4	5178·00 }	5b	19306·8
5199·86 }		19225·6	5177·56 }		19308·4
5199·53	2	19226·8	5177·30	2 } b	19309·4
5199·29	2	19227·7	5177·05	4 }	19310·3
5199·00	4⊙	19228·8	5176·66	3 }	19311·8
5198·21	5	19231·7	5176·39	5	19312·8
5197·90	5	19232·8	5176·07	5	19314·0
5197·49	4	19234·4	5175·68	5	19315·4
5197·17	2	19235·5	5175·41	2	19316·4
5196·91	4	19236·5	5174·91	7	19318·3
5196·69	5	19237·3	5174·46	4	19320·0
5196·41	4	19238·3	5173·82	5	19322·4
5196·04	4	19239·7	5173·52	5	19323·5
5195·52	4	19241·6	5172·72	5	19326·5
5194·94	3	19243·8	5172·43	3	19327·6
5194·63	3	19244·9	5171·64	3	19330·5
5194·24	5	19246·7	5171·08	3	19332·6
5193·96	2	19247·4	5170·78	4	19333·7
5193·61	4	19248·7	5170·60	4	19334·4
5193·28	5	19249·9	5170·36	3	19335·3
5193·00	5	19251·0	5170·11	3	19336·2
5192·34	3	19253·4	5169·85	4	19337·2
5191·80	5⊙	19255·4	5169·60	3	19338·2
5191·52	2	19256·5	5168·26	6	19343·2
5191·28	3	19257·4	5167·41	6	19346·4
5190·92	3	19258·7	5167·04	4	19347·7
5190·50	4	19260·3	5166·87	2	19348·4
5190·14	3	19261·6	5166·31	4	19350·5
5189·59	6	19263·6	5165·93	4	19351·9
5188·76	4	19266·7	5165·39	4	19353·9
5188·22	5	19268·7	5165·05	4	19355·2
5187·88	5	19270·0	5164·31	5	19358·0
5187·55	3	19271·2	5163·86	4	19359·6
5187·23	5	19272·4	5163·35	6*	19361·6
5186·89	2	19273·7	5163·00	3	19362·9
5186·55	5	19274·9	5162·30	4	19365·5
5186·00	4 }	19277·0	5161·93	5	19366·9
5185·46*	5 } b	19279·0	5161·47 }	5	19368·6
5185·17 }	5 }	19280·1	5161·23 }		19369·5
5184·92 }		19281·0	5160·54	6v.	19372·1
5184·57	6	19282·3	5159·97	4	19374·2
5184·29	6	19283·3	5159·70	2	19375·3

Aluminium Oxide (Arc Spectrum).

Hasselberg, 'Kongl. Svenska Vetenskaps-Akademiens Handlingar,' Bandet 24, 1892.

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
Group 44	71–4648				4483·50		1·33	6·6	22297·4
					4483·81	5bs	1·34		22295·9
4470·63	8	1·33	6·7	22361·5	4483·95				22295·2
4471·18	b			22358·8	4484·19	5			22294·0
4471·30				22358·2	4484·90	4			22290·4
4471·49	3			22357·2	4485·12	4 b			22289·3
4471·67	2			22356·3	4485·27	4			22288·6
4471·86	4		6·7	22355·4	4485·64	5			22286·8
4472·11	4		6·6	22354·2	4485·81	3 b'			22285·9
4472·33	4			22353·1	4485·97	2			22285·1
4472·59	3			22351·8	4486·41	4			22282·9
4472·87*	5			22350·4	4486·59	4			22282·0
4473·16*	4			22349·0	4486·75	4			22281·2
4473·48*	4			22347·4	4487·11	4			22279·5
4473·78*	4			22345·9	4487·40	3			22278·0
4474·09	5n			22343·3	4487·56	5			22277·2
4474·51	6n			22342·2	4487·95	4			22275·3
4474·89	5			22340·3	4488·18	3			22274·1
4475·00	3			22339·8	4488·37	3			22273·2
4475·25	5			22338·5	4488·75	5n			22271·3
4475·36	2			22338·0	4489·02	3			22270·0
4475·69	5			22336·3	4489·18	3			22269·2
4475·80	2			22335·8	4489·30	2			22268·6
4476·58	5			22331·9	4489·61	5n			22267·0
4476·79				22330·8	4489·86	4			22265·8
4477·00	5			22329·8	4490·04	3			22264·9
4477·23	2			22328·6	4490·26	2			22263·8
4477·59	5			22326·8	4490·46*	4			22262·8
4477·87	2			22325·4	4490·73	5			22261·5
4478·09	4			22324·3	4490·89	5			22260·7
4478·22	3			22323·7	4491·10	2			22259·7
4478·45	2			22322·5	4491·34*	4			22258·5
4478·64	6			22321·6	4491·63	4			22257·0
4478·79	2			22320·9	4491·76	4			22256·4
4479·17	5			22319·0	4492·05	3			22254·7
4479·38	3			22317·9	4492·21*	4			22254·2
4479·70	5b			22316·3	4492·49	4			22252·8
4479·91				22315·3	4492·69	4			22251·8
4480·34	5			22313·1	4493·10	5			22249·7
4480·53	3			22312·2	4493·38	4			22248·4
4480·83	5b			22310·7	4493·58	3			22247·4
4481·02				22309·7	4494·02	2			22245·2
4481·13	2			22309·2	4494·22	9			22244·2
4481·31	2			22308·3	4495·38	4			22238·5
4481·52	3			22307·3	4495·55	4			22237·6
4481·77				22306·0	4495·81	4 b			22236·3
4482·14	4n			22304·2	4495·98	5			22235·5
4482·63	3			22301·7	4496·30	5			22233·9
4482·82	5b			22300·8	4496·56	4			22232·6
4483·22				22298·8	4496·86	6n			22231·1

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4497·19	3	1·34	6·6	22229·5	4508·57	2	1·34	6·6	22173·4
4497·30	3			22229·0	4508·80	4			22172·2
4497·53	4			22227·8	4508·98	5			22171·4
4497·91*	5			22225·9	4509·10	5			22170·8
4498·29	4			22224·1	4509·55	5			22168·6
4498·49	2			22223·1	4509·77	5			22167·5
4498·67	2			22222·2	4510·03	2			22166·2
4498·88	2			22221·1	4510·15	2			22165·5
4499·06*	4			22220·3	4510·32	2			22164·8
4499·41	4			22218·5	4510·48	5			22164·0
4499·53				22217·9	4510·61	5			22163·3
4499·71	2			22217·0	4510·83	2			22162·3
4499·92	5			22216·0	4511·06	4			22161·1
4500·00				22215·6	4511·25	6			22160·2
4500·16	2			22214·8	4511·38	6			22159·6
4500·43*	5			22213·5	4511·89	3			22157·1
4500·63	4			22212·5	4512·07	6			22156·2
4500·86	4			22211·4	4512·20	6			22155·5
4500·99	4			22210·7	4512·48	3			22154·2
4501·10	4			22210·2	4512·67	5			22153·2
4501·34	4			22209·0	4512·91	5			22152·0
4501·51	4			22208·2	4513·05	4			22151·4
4501·65	4			22207·5	4513·35	4			22149·9
4501·86	3			22206·4	4513·52	4			22149·1
4502·00	5			22205·7	4513·71	4			22148·1
4502·13	5			22205·1	4513·84	4			22147·5
4502·37	4⊙			22203·9	4514·39	4			22144·8
4502·53	4			22203·1	4514·63*	5b			22143·6
4502·72	5			22202·2	4515·03	3			22141·6
4502·98	3			22200·9	4515·18	3			22140·9
4503·13	5			22200·2	4515·27	3			22140·5
4503·23	5			22199·6	4515·42	4			22139·7
4503·51	3			22198·3	4515·59	3			22138·9
4503·69	4			22197·2	4515·95	3			22137·1
4503·84	3			22196·7	4516·17	4			22136·1
4504·14	5b			22195·2	4516·37	4			22135·1
4504·43				22193·8	4516·54	10			22134·2
4504·74	4			22192·2	4517·04	3			22131·8
4504·89	4			22191·5	4517·27	4			22130·7
4505·02	4			22190·9	4517·39	3			22130·1
4505·36	5			22189·2	4517·64	3			22129·8
4505·54	3			22188·3	4517·82	3			22128·0
4505·68	5			22187·6	4517·98	4			22127·2
4506·01	4			22186·0	4518·16	4s			22126·3
4506·17	4			22185·2	4518·27	2			22125·8
4506·31	3 b			22184·5	4518·44	2			22124·9
4506·67	4			22182·7	4519·00	3			22122·2
4506·86	2			22181·8	4519·14	4			22121·5
4506·99	4			22181·2	4519·28	3			22120·8
4507·35	4			22179·4	4519·67*	4			22118·9
4507·53	5			22178·5	4519·94	4	1·34		22117·6
4507·65	3n			22177·9	4520·10	5	1·35		22116·8
4508·08	3			22175·8	4520·36	4			22115·5
4508·26	3			22174·9	4520·47	4			22115·0
4508·37	5			22174·4	4520·71	3			22113·8

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4520·84	4	1·35	6·6	22113·2	4534·49	4b	1·35	6·6	22046·6
4521·08	6			22112·0	4535·13	5 } b			22043·5
4521·19	5			22111·5	4535·48	3s }			22041·8
4521·65	5			22109·2	4535·67*	3			22040·9
4521·90	5			22108·0	4535·92	4			22039·6
4522·08	6			22107·1	4536·05	2			22039·0
4522·40	4			22105·5	4536·16	2			22038·5
4522·53	5			22104·9	4536·52	3			22036·7
4522·86 }	7b			22103·3	4536·75*	6			22035·6
4523·45 }				22100·4	4537·00	4			22034·4
4523·85	4 }			22098·5	4537·69	10			22031·0
4523·98	5 } b			22097·8	4537·98	}			22029·6
4524·20*	4 }			22096·7	4538·14	} b			22028·9
4524·47	5 }			22095·4	4538·33	}			22027·9
4524·66	2			22094·5	4538·55	5 }			22026·8
4524·88	4			22093·4	4538·80	2			22025·5
4525·04	5			22092·5	4539·28	2			22023·3
4525·47	3			22091·5	4539 46*	6			22022·4
4525·58	4			22090·0	4539·73	2		6·6	22021·1
4525·95	4			22088·2	4540·36*	6		6·5	22018·2
4526·14	5			22087·3	4540·65*	6			22017·8
4526·33	4			22086·3	4540·92	3			22016·5
4526·62	4			22084·9	4541·08	2			22015·7
4526·75	4			22084·3	4541·33	6b			22013·5
4527·23	5			22082·0	4541·57	2			22012·3
4527·42	6⊙			22081·0	4541·72	2			22011·6
4527·87	5			22078·8	4541·86	2			22010·9
4528·01	4			22078·2	4542·03	4s			22010·1
4528·56	6 } bn			22075·5	4542·24*	4			22009·1
4528·74	}			22074·6	4542·50*	4			22007·8
4529·01	2			22073·3	4542·84	3			22006·2
4529·19	4			22072·4	4543·04	2			22005·2
4529·30	4			22071·9	4543·23*	7			22004·3
4529·48	4			22071·0	4543·71	4			22001·9
4529·69	4			22070·0	4543·90	3			22001·0
4529·87	4			22069·1	4544·17 }	6			21999·7
4530 00	4			22068·8	4544·28 }				21999·2
4530·22	2			22067·4	4544·53	3			21998·0
4530·38	2			22066·6	4544·71	5			21997·1
4530·53	4			22065·9	4545·15	5			21995·0
4530·68	5			22065·1	4545·29	5			21994·3
4530·84	4⊙			22064·4	4545·52	2			21993·2
4531·27	5⊙			22062·3	4545·70	4			21992·3
4531·42	4			22061·5	4545·91	3			21991·3
4531·81	5			22059·6	4546·10 }	5b (4			21990·4
4532·00	6s			22058·7	4546·39 }	lines)			21989·0
4532·13	4			22058·1	4546·57	3			21988·1
4532·76	5			22055·0	4546·79	4			21987·0
4532·93	3			22054·2	4546·94	3			21986·3
4533·04	4			22053·6	4547·18	3			21985·1
4533·20	4 }			22052·9	4547·33	6			21984·4
4533·36	3 } b			22052·1	4547·53	5			21983·5
4533·54	5 }			22051·2	4547·91*	4b			21981·6
4533·68	4 }			22050·5	4548·15	3			21980·5
4534·24	8b			22047·8	4548·27	2			21979·9

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4548·40	4	1·35	6·5	21979·2	4560·38	4	1·36	6·5	21931·5
4548·58	2			21978·4	4560·56	3			21930·6
4548·71	4			21977·5	4560·69	3			21930·0
4548·93	2			21976·7	4560·88	3 b			21929·1
4549 18	4			21975·5	4561·02	2			21928·4
4549·36	4			21974·6	4561·21	4			21927·5
4549 51	4			21973·9	4561·39	4			21926·6
4549·77*	5			21972·6	4561·48	3			21926·2
4550·02	2			21971·4	4561·75	4			21924·9
4550·16	2			21970·7	4562·17	4			21922·9
4550·40	6			21969·6	4562·30	5			21922·3
4550·65*	5			21968·4	4562·47	5			21921·4
4550·90	2			21967·2	4562·70	4			21920·3
4551·10*	4			21966·2	4563·12	4			21918·3
4551·33	2			21965·1	4563·34	4			21917·3
4551·54	2			21964·1	4563·57	4			21906·2
4551·83	5			21962·7	4563·77	4			21905·2
4552·04	4			21961·7	4564·01	4			21904·0
4552·22	3			21960·8	4564·26	4			21902·8
4552·55	5bn			21959·2	4564·47	2			21901·8
4552·81	3			21958·0	4564·71	3			21900·7
4552·91	2			21957·5	4565·48	3 b			21897·0
4553·15	4b			21956·3	4565·69	4			21896·0
4553·30				21955·6	4565·98	3			21895·6
4553·48	3			21954·7	4566·17*	5			21893·7
4553·79	3			21953·2	4566·40	3			21892·6
4554·01*	6			21952·2	4566·99	4			21889·8
4554·29*	4			21950·8	4567·10	2			21889·2
4554·65	4			21959·1	4567·32	4			21888·2
4554·80	3s			21958·4	4567·55	4			21887·1
4554·98	4	1·35		21957·5	4567·74	2			21886·2
4555·14	2	1·36		21956·7	4567·95	4			21885·2
4555·24	3			21956·2	4568·15	3			21884·2
4555·44	4			21955·3	4568·35	3			21883·2
4555·57	5			21954·6	4568·56	3			21882·2
4555·83	3			21953·4	4568·79	3			21881·1
4556·14	4			21951·9	4569·01	5			21880·1
4556·46	2			21950·4	4569·13	5			21879·5
4556·66	3			21949·4	4569·40	5			21878·2
4556·78	3			21948·9	4569·66	4			21877·0
4557·06	4			21947·5	4569·76	5			21876·5
4557·20	4			21946·8	4570·02	4			21875·2
4557·37	2			21946·0	4570·24	5			21874·2
4557·52	3			21945·3	4570·44	6			21873·2
4557·84	8			21943·7	4570·67	4			21871·5
4558·27	3			21941·6	4571·11	5			21870·0
4558·55	2			21940·3	4571·30	4			21869·1
4558·71	4			21939·5	4571·51	3			21868·1
4558·85	4			21938·8	4571·65	4†			21867·4
4559·09	5			21937·7	4571·87				21866·4
4559·33	2			21936·5	4572·22*	4			21864·7
4559·52	3†			21935·6	4572·42	5			21863·7
4559·75				21934·5	4572·60	3			21862·9
4559·93	4			21933·7	4572·73	2			21862·3
4560·14	2			21932·6	4572·95	4			21861·2

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
4573·13	4	1·36	6·5	21860·4	4585·47	4	1·36	6·5	21801·5
4573·31	4			21859·5	4585·76	3			21800·1
4573·48	3			21858·7	4585·96*	4			21799·2
4573·71	4			21857·6	4586·27	4			21797·7
4573·87	4			21856·8	4586·50	4			21796·6
4574·05	4			21855·0	4586·69	4			21795·7
4574·19	2			21855·3	4586·88	4			21794·8
4574·48	4b			21853·9	4587·12	3			21793·7
4574·67	4b			21853·0	4587·22				21792·2
4574·91	2n			21851·8	4587·48	4			21792·0
4575·18	3			21850·6	4587·69	3			21791·0
4575·37	2			21849·6	4587·84	4			21790·2
4575·57	3			21848·7	4588·08	3			21789·1
4575·76	2			21847·8	4588·26	4			21788·2
4575·98	3			21846·7	4588·51	4			21787·1
4576·18	3			21845·8	4588·71	2			21786·1
4576·47	6			21844·4	4588·89	3	1·36		21785·3
4576·76	5 b			21843·0	4589·17	2	1·37		21783·9
4577·00	5			21841·9	4589·55	3b^r			21782·1
4577·22	2			21840·8	4589·73	2			21781·3
4577·37	3			21840·1	4589·87	3			21780·6
4577·56	3			21838·2	4590·14	3			21779·3
4577·71	3			21838·5	4590·30	3			21778·6
4577·88	3			21837·5	4590·50	3			21777·6
4578·11	4			21836·6	4590·80	4			21776·2
4578·40	2			21835·2	4590·95	4			21775·5
4578·58	4			21834·3	4591·21	3			21774·2
4578·93	3			21832·7	4591·35	2			21773·6
4579·18	5n			21831·5	4591·57	3 b			21772·5
4579·46*	3			21830·1	4591·73	3			21771·8
4579·84	2			21828·3	4591·86	3			21771·2
4580·07	3			21827·2	4592·07*	4			21770·2
4580·25	3			21826·4	4592·29	3b			21769·1
4580·43*	4			21825·5	4592·46	3			21768·3
4580·70	3			21824·2	4592·64	3			21767·5
4580·94	3			21823·1	4592·92	3			21766·1
4581·18	5			21821·9	4593·14	4			21765·1
4581·52	4			21820·3	4593·42	4			21763·8
4581·68	3			21819·5	4593·50				21763·4
4581·96	3			21818·2	4593·72	4			21762·3
4582·07	3			21817·5	4593·97	6			21761·2
4582·19	2			21817·1	4594·25	4			21759·8
4582·44	4			21815·9	4594·51	3			21758·6
4582·71	5			21814·7	4594·68	4			21757·8
4582·96	5			21813·5	4594·87	4			21756·9
4583·46*	2			21811·1	4595·13	b			21755·7
4583·71	4			21809·9	4595·39	4			21754·4
4583·93	4			21808·8	4595·63	2			21753·3
4584·18	3			21807·6	4595·86	2			21752·2
4584·36	3			21806·8	4596·05*	5			21751·3
4584·58	4			21805·5	4596·25	4			21750·4
4584·77	3			21804·6	4596·35				21749·9
4584·89	3			21803 3	4596·53*	2			21749·1
4585·02	2			21803·6	4596·82	4			21747·7
4585·23	4			21802·6	4596·93	4			21747·1

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
4597·16	2	1·37	6·5	21746·1	4611·94	2	1·37	6·4	21676·4
4597·40	3			21744·9	4612·12	3			21675·6
4597·60*	4bn			21744·0	4612·32	2			21674·7
4597·86*	3			21742·7	4612·48	2			21673·9
4598·55	4			21739·5	4612·63	3			21673·2
4598·82	2			21738·2	4612·85	4			21672·2
4598·99	3			21737·4	4613·16	3			21670·7
4599·28 }	5			21736·0	4613·46	4			21669·3
4599·41 }				21735·4	4613·85*	3			21667·5
4599·79	4n			21733·6	4614·09	2			21666·3
4600·22	4			21731·6	4614·27	2			21665·5
4600·43	3			21730·6	4614·49	4			21664·5
4600·71	4			21729·3	4614·78	4			21663·1
4601·16	3n			21727·1	4615·00	3			21662·1
4601·36	2n			21726·2	4615·22	3			21661·0
4601·65	4n			21724·8	4615·43	2			21660·0
4601·94	4n			21723·5	4616·14	4n } b			21656·7
4602·41	2			21721·2	4616·68	4n }			21654·2
4602·58	3			21720·4	4616·97	3			21653·8
4602·88*	4			21719·0	4617·20 }	3†			21651·7
4603·43*	4			21716·4	4617·45 }				21650·6
4603·72*	4			21715·1	4617·66	3			21649·6
4604·02*	2			21713·6	4618·00	3			21648·0
4604·17	2			21712·9	4618·14	2			21647·3
4604·39*	2			21711·9	4618·39*	3			21646·2
4604·73	4⊙			21710·3	4618·64	2			21645·0
4604·95	3			21709·3	4618·84	3			21644·1
4605·25	4			21707·8	4619·10	3			21642·8
4605·60 }	4			21705·2	4619·46 }	3⊙			21641·1
4605·69 }				21706·8	4619·78 }				21639·6
4605·93	4			21704·6	4620·01	2			21638·6
4606·28	2n			21703·0	4620·24	2			21637·5
4606·48	3			21702·0	4620·54	4			21636·1
4606·65	2			21701·2	4620·77	3			21635·0
4606·85	3			21700·3	4620·95 }				21634·2
4607·13*	4			21699·0	4621·14 }	3b			21633·3
4607·38	2			21698·8	4621·32 }				21632·4
4607·51	2			21697·2	4621·52	2			21631·5
4607·68*	3			21696·4	4621·73	2			21630·5
4608·01 }	5			21694·8	4621·95	5			21629·5
4608·12 }				21694·3	4622·20	2			21628·3
4608·40*	5			21693·0	4622·39	4			21627·4
4608·62	2		6·5	21692·0	4622·53	2			21626·8
4608·91	4		6·4	21690·6	4622·84	5			21625·4
4609·73	4			21686·8	4623·20	4			21623·6
4609·88	2			21686·1	4623·45	4			21622·5
4609·96	2			21685·8	4623·85	3			21620·6
4610·14	4			21684·9	4624·17	3			21619·1
4610·27	3			21684·3	4624·40	3			21618·0
4610·51	2			21683·2	4624·58	3			21617·2
4610·74	5			21682·1	4624·76	3			21616·3
4610·94	2			21681·1	4624·96	4			21615·4
4611·09	4			21680·4	4625·30	4n	1·37		21613·8
4611·20	3			21679·9	4625·67 }	4b	1·38		21612·1
4611·53	3bv			21678·4	4625·77 }				21610·8

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4626·14	4b	1·38	6·4	21609·9	4640·83	3†	1·38	6·4	21541·5
4626·36				21608·9	4641·07				21540·3
4626·52				21608·1	4641·29	3			21539·3
4626·74	4			21607·1	4641·45	2			21538·6
4626·89	4			21606·4	4641·72	3n			21537·3
4627·07	2			21605·7	4641·96	2			21536·2
4627·28	2			21604·6	4642·15	2			21535·3
4627·42	2			21603·9	4642·36	3b^{v}			21534·4
4627·73	4			21602·5	4642·82	2			21532·2
4628·00	3			21601·2	4643·01	2			21531·3
4628·20	3			21600·3	4643·21	2			21530·4
4628·51	4			21598·8	4643·39	2			21529·6
4628·83	3			21597·3	4644·39	2			21524·9
4629·18	2			21595·7	4644·65	5n			21523·7
4629·33	2			21595·0	4644·95	4			21522·4
4629·81	2			21592·8	4645·09	3			21521·7
4629·96	4			21592·1	4645·37	3			21520·4
4630·30	4⊙			21590·5	4645·61	2			21519·3
4630·62	2			21589·0	4645·94	2			21517·8
4631·07	3			21586·9	4646·09	2			21517·1
4631·34	2			21585·6	4646·43	4n			21515·5
4631·56	2			21584·6	4646·79	3			21513·8
4631·76	2			21583·7	4647·28	2			21511·6
4631·98	2			21582·6	4647·47	2			21510·7
4632·13	3			21581·9	4647·79	2			21509·2
4632·28	3			21581·2	4648·07	2			21507·9
4632·64	4			21579·6					
4633·02	2			21577·8					
4633·18	3			21577·0	Group 4648	–4842			
4633·44	2			21575·8					
4633·56	3			21575·3	4648·14	12			21507·6
4633·98	3 b			21573·3	4648·99	3			21503·6
4634·43	2			21571·2	4649·11	4			21503·1
4634·61	2			21570·4	4649·31	4			21502·2
4634·77	3			21569·6	4649·47	4			21501·4
4634·94	2			21568·8	4649·69	4			21500·4
4635·10	2			21568·1	4649·89	4			21499·5
4635·21	2			21567·6	4650·12	4			21498·4
4635·41	3			21566·7	4650·39	4*			21497·2
4635·72	2			21565·2	4650·67	4* n			21495·9
4635·87	3			21564·5	4650·97	4*			21494·5
4636·04	2			21563·7	4651·27	5*			21493·1
4636·18	2			21563·1	4651·58	5			21491·7
4636·35	3			21562·3	4651·67				21491·2
4636·48	2			21561·7	4651·94	5			21490·0
4636·84	4			21560·0	4652·04				21489·5
4637·29	3			21557·9	4652·30	5			21488·3
4637·56	3			21556·7	4652·37				21488·0
4638·55*	2			21552·1	4652·68	4			21486·6
4638·91	4 b			21550·4	4652·78	3			21486·1
4639·23*	3			21548·9	4653·06	4			21484·8
4639·54	4n			21548·5	4653·18	3			21484·3
4640·08	2			21544·9	4653·51	4			21482·7
4640·33	2			21543·8	4653·61	3			21482·3
4640·62*	3			21542·4	4653·94	4			21480·8

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4654·04	4	1·38	6·4	21480·3	4668·04	5	1·39	6·4	21415·9
4654·40	5			21478·6	4668·36	4			21414·4
4654·52	4			21478·1	4668·54	4			21413·6
4654·86	5			21476·5	4668·86*	5			21412·1
4655·02	4			21475·8	4669·22	4			21410·4
4655·34	6			21474·3	4669·40	4			21409·5
4655·50	4			21473·6	4669·72	5			21408·2
4655·86	5			21471·9	4669·79				21407·8
4656·02	4			21471·2	4670·12	4			21406·3
4656·42	6			21469·3	4670·29	4			21405·5
4656·57	4			21468·6	4670·62	5			21404·0
4656·91	6			21467·1	4670·72				21403·6
4657·10	4			21466·2	4671·02	4			21402·2
4657·51	6			21464·3	4671·21	4			21401·3
4657·70	4			21463·4	4671·53	5			21399·9
4658·07	6			21461·7	4671·61				21399·5
4658·27	4			21460·8	4671·97	2			21397·8
4658·68*	6			21458·9	4672·15	12			21397·0
4658·91	4			21458·8	4672·48				21395·5
4659·25	5			21456·3	4672·62				21394·9
4659·35				21455·8	4672·97	4			21393·3
4659·55	4			21454·9	4673·14	4			21392·5
4659·88	5			21453·4	4673·43	3s			21391·2
4659·98				21452·9	4673·58	4			21390·5
4660·18	4			21452·0	4673·80	2			21389·5
4660·54	5			21450·3	4673·91	3			22389·0
4660·67	4			21449·7	4674·09	4			21388·1
4660·81	4	1·38		21449·1	4674·38	5			21386·8
4661·20	5	1·39		21447·3	4674·53	4			21386·1
4661·34	4			21446·7	4674·71	3			21385·3
4661·54	4			21445·7	4674·90	4		6·4	21384·4
4661·91	5			21444·0	4675·15*	3		6·3	21383·4
4662·08	4			21443·2	4675·37	3			21382·4
4662·22	4			21442·6	4675·51	4			21381·7
4662·61	5			21440·8	4675·65	3			21381·1
4662·78	4			21440·0	4675·91	4 b			21379·9
4662·96	5			21439·2	4676·37	4			21377·8
4663·33	5			21437·5	4676·52	2			21377·1
4663·51	4			21436·7	4676·66	2			21376·5
4663·66	5			21436·0	4676·81	2			21375·8
4664·07	5			21434·1	4676·96	4			21375·1
4664·30	4			21433·0	4677·10	4 b			21374·5
4664·45	4			21432·3	4677·20	4			21374·0
4664·81	5			21430·7	4677·38	4			21373·2
4665·05	4			21429·6	4677·50	5 b			21372·6
4665·24	4			21428·7	4677·61	3			21372·1
4665·62	5			21427·0	4677·84	2			21371·1
4665·85	4			21425·9	4677·95	5			21370·6
4666·03	4			21425·1	4678·03				21370·2
4666·38	5			21423·5	4678·24	3			21369·3
4666·67	4			21422·1	4678·41	5			21368·5
4666·85	4			21421·3	4678·55	5			21367·8
4667·22	5			21419·6	4678·74	2			21367·0
4667·50	4			21418·3	4678·91	2			21366·2
4667·67	4			21417·6	4679·23	3			21364·7

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4679·51	4s	1·39	6·3	21363·5	4691·18	3	1·39	6 3	21310·3
4679·89	2			21361·7	4691·40	3			21309·3
4680·04	2			21361·0	4691·71	3			21307·9
4680·21	2			21360·3	4691·84	3			21307·3
4680·38	3			21359·5	4692·06	3			21306·3
4680·56	4s			21358·7	4692·27	5			21305·3
4680·71	3			21358·0	4692·45	5 b			21304·5
4680·68	3			21356·7	4692·58	4			21303·9
4681·13	2			21356·1	4692·67	4			21303·5
4681·30	3 b			21355·3	4693·11	4			21301·5
4681·66*	4			21353·6	4693·33	4 b			21300·5
4681·90	2			21352·5	4693·55	4			21299·5
4682·31*	3			21350·7	4693·67	3			21299·0
4682·52*	3			21349·7	4693·98	4			21297·6
4682·73	5s			21348·7	4694·20	3			21296·6
4682·85	5s			21348·2	4694·29	3			21296·2
4683·08	3			21347·1	4694·40	3			21295·7
4683·37	4			21345·8	4694·78	12n			21293·9
4683·52	4s			21345·2	4695·30				21291·6
4683·69	4			21344·4	4695·59	2			21290·3
4683·86	2 b			21343·3	4695·80				21289·3
4684·00	4			21343·0	4696·01	6b	1·39		21288·4
4684·17	3			21342·2	4696·30		1·40		21287·1
4684·37	4			21341·3	4696·43	2			21286·5
4684·66	5			21340·0	4696·56	2			21285·9
4684·85	4 b			21339·1	4696·73	5			21285·1
4685·01	5			21338·4	4696·97	6 b			21284·0
4685·11	4			21337·9	4697·37	3			21282·2
4685·32	3			21337·0	4697·52	3			21281·5
4685·51	3			21336·1	4697·65	6			21280·9
4685·69*	3			21335·3	4697·90	6			21279·8
4685·84	2			21334·6	4698·07	2			21279·0
4686·03	4s b			21333·7	4698·20	2			21278·4
4686·18	4s			21333·0	4698·34	3			21277·8
4686·72	3			21330·6	4698·57	2			21276·8
4686·91	2			21329·7	4698·70	4			21276·2
4687·07	4			21329·0	4698·90	6 b			21275·3
4687·35	3 b			21327·7	4699·00	7			21274·8
4687·48	4s			21327·1	4699·30	2			21273·5
4687·66	2			21326·3	4699·45	2			21272·8
4687·83	4			21325·5	4699·69	3			21271·7
4688·23	5			21323·7	4699·87	5			21270·9
4688·56	5			21322·2	4700·01	2			21270·2
4688·69	4			21321·6	4700·17	4			21269·5
4688·97	4			21320·3	4700·35	4			21268·7
4689·19	3			21319·3	4700·44	2			21268·3
4689·32	4			21318·7	4700·68	3			21267·2
4689·49				21318·0	4700·89	5			21268·3
4689·77	6			21316·7	4701·04	5			21265·6
4689·95	5			21315·9	4701·18	3			21265·0
4690 11	4			21315·2	4701·30	3			21264·4
4690·19				21314·8	4701·56	4			21263·2
4690·58	3			21313·0	4701·74	4 b			21262·4
4690·80	4			21312·0	4701·91	4			21261·7
4691·00	5			21311·1	4702·01	4			21261·2

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
4702·17	2	1·40	6·3	21260·5	4713·55	4	1·40	6·3	21209·1
4702·27				21260·0	4713·84	4			21207·8
4702·53	3			21258·8	4714·06	4			21206·9
4702·70	4b			21258·1	4714·19	5			21206·2
4702·97	6b			21256·9	4714·37	3			21205·4
4703·64	3			21253·8	4714·44				21205·1
4703·80	4			21253·1	4714·69	2			21204·0
4704·02	4			21252·1	4714·88	6			21203·1
4704·14	4			21251·6	4715·07	4			21202·3
4704·39	5b			21250·4	4715·45	6			21200·6
4704·60	3			21249·5	4715·74	4			21199·3
4704·75	3			21248·8	4716·02	5			21198·0
4704·91	3			21248·1	4716·40	4 b			21196·8
4705·07	4			21247·4	4716·68	5			21195·1
4705·16				21247·0	4716·87	4			21194·2
4705·35	2			21246·1	4717·04	3			21193·4
4705·51	3			21245·4	4717·31	3			21192·2
4705·62	3			21244·9	4717·49	5			21191·4
4705·89	7			21243·7	4718·00	6			21189·1
4706·01				21243·1	4718·11	6			21188·6
4706·17	7			21242·4	4718·33	6			21187·6
4706·26				21242·0	4718·47	6			21187·0
4706·57	3			21240·6	4718·80	3			21185·5
4706·77	4			21239·7	4719·00	2			21184·6
4706·88	3			21239·2	4719·12	2			21184·1
4707·10	2			21238·2	4719·29	7			21183·3
4707·26	7†b			21237·5	4719·41				21182·8
4707·53				21236·3	4719·68	4			21181·6
4707·88	3			21234·7	4719·89	3			21180·6
4708·10	3			21233·7	4720·05	3			21179·9
4708·25	3			21233·0	4720·21	2			21179·2
4708·38	3			21232·4	4720·32	4			21178·7
4708·51	4			21231·8	4720·61	3			21177·4
4708·77	6			21230·7	4720·76	4			21176·7
4708·94	6			21229·9	4721·02	3			21175·6
4709·23	4			21228·6	4721·17	2⊙			21174·9
4709·45	6			21227·3	4721·27	4 b			21174·4
4709·62	6			21226·8	4721·38	2			21173·9
4709·99	2			21225·2	4721·59	4			21173·0
4710·21*	6b			21224·2	4721·89	4			21171·7
4710·44	4			21223·1	4722·08	6			21170·8
4710·61	b			21222·1	4722·26	4 b			21170·0
4710·80	4			21221·5	4722·36	4			21169·5
4710·97	3			21220·7	4722·56*	3			21168·7
4711·08	2			21220·3	4722·80	2			21167·3
4711·47	3			21218·5	4723·01	5			21166·6
4711·69	5			21217·5	4723·26	5			21165·5
4711·81	8			21217·0	4723·47	4			21164·3
4711·98	8			21216·2	4723·59	2			21164·0
4712·27	3			21214·9	4723·78*	2			21163·2
4712·47	4			21214·0	4723·99	3			21162·2
4712·57	3			21213·5	4724·09	3			21161·8
4712·97	6			21211·7	4724·27	4			21161·0
4713·16	5			21210·9	4724·52	2 b			21159·9
4713·35				21210·0	4724·63	4			21159·4

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4724·86	4 } b	1·40	6·3	21158·3	4736·80	2	1·41	6·3	21105·0
4725·13	4 }			21157·1	4736·94	5			21104·4
4725·30	4 }			21156·4	4737·20	4			21103·2
4725·61	4			21155·0	4737·38	4			21102·4
4725·72	2			21154·5	4737·61	5			21101·4
4726·03	5			21153·1	4737·86	4			21100·3
4726·24*	6b			21152·2	4738·17	4			21098·9
4726·59	4			21150·6	4738·50	5			21097·4
4726·83	3			21149·5	4738·75	5			21096·3
4727·20	4			21148·9	4739·00	4			21095·2
4727·40	6			21147·0	4739·17	4			21094·4
4727·81	2			21145·1	4739·42	5			21093·3
4728·01	4 }			21144·2	4739·78	5			21091·7
4728·17	5 }			21143·5	4739·99	4 } b			21090·8
4728·41	5 }			21142·5	4740·35	4 }			21088·2
4728·67	3			21141·3	4740·67	4			21087·8
4728·81	5			21140·7	4740·75	4			21087·4
4728·97	4			21139·9	4740·93	4 } b			21086·6
4729·10	4			21139·4	4741·26	5 }			21085·1
4729·29	5			21138·5	4741·57	3			21083·8
4729·43	5n			21137·9	4741·73	3			21083·0
4729·81*	3			21136·2	4742·06	3			21081·6
4730·03*	3			21135·2	4742·22	3			21080·9
4730·22	3			21134·4	4742·37	4			21080·2
4730·41	5			21133·5	4742·56	6s			21079·4
4730·58	4			21132·8	4442·79	4			21078·3
4730·68	4			21132·3	4742·99	4			21077·4
4730·88	3	1·40		21131·4	4743·16	4			21076·7
4731·15	2	1·41		21130·2	4743·37	3			21075·8
4731·37	3			21129·2	4743·65	4			21074·5
4731·52	5			21128·6	4743·85 } 5				21073·6
4731·69	5			21127·8	4743·94 }				21073·2
4731·82	5			21127·2	4744·14	5			21072·3
4732·08	3			21126·0	4744·45	4			21071·0
4732·37	2			21124·8	4744·70	4			21069·8
4732·62	4			21123·6	4744·95 } 6				21068·7
4732·81	4			21122·8	4745·17 }				21068·0
4732·96	2			21122·1	4745·57	4			21066·0
4733·11	3			21121·5	4745·83	4			21064·8
4733·35	5			21120·4	4446·11	4			21063·6
4733·46	5			21119·9	4746·30	4			21062·7
4733·77	4			21118·5	4746·53	4			21061·7
4733·97	2			21117·6	4746·64	4			21061·2
4734·14	3			21116·9	4746·95	4			21059·9
4734·35	3			21115·9	4747·12	3			21059·1
4734·62	3			21114·7	4747·23	4			21058·6
4734·83	4 }			21113·8	4747·47	4			21057·5
4734·96	4 } b			21113·2	4747·64	4			21056·8
4735·13	6 }			21112·4	4747·85 } 5				21055·9
4735·35	5 }			21111·5	4747·96 }				21055·4
4735·71	2			21109·8	4748·18	3		6·3	21054·4
4735·94 } 7				21108·8	4748·33	4		6·2	21053·8
4736·08 }				21108·2	4748·57	3			21052·8
4736·32	5			21107·1	4748·88	4			21051·4
4736·53	3			21106·2	4749·02	2			21050·8

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4749·19	6	1·41	6·2	21050·0	4761·02	3	1·41	6·2	20997·7
4749·51	2			21048·6	4761·28	3			20996·5
4749·74	4			21047·6	4761·52	4s } b			20999·5
4750·01	4			21046·4	4761·80	}			20994·3
4750·26	3			21045·3	4762·07	5bn			20993·1
4750·42	2			21044·6	4762·34	3			20991·9
4750·56	5			21043·9	4762·51	5⊙			20991·1
4750·84	4			21042·7	4762·69 }	5			20990·3
4751·13	4			21041·4	4762·81 }				20989·8
4751·33	3			21040·5	4763·02*	5			20988·9
4751·81	4			21038·4	4763·60	4b^r			20986·3
4752·09	3			21037·2	4763·85	3			20985·2
4752·27	7			21036·4	4764·02	4			20984·5
4752·53	7			21035·2	4764·25	3			20983·5
4752·75	2			21034·2	4764·46 } b				20982·5
4753·00	2			21033·1	4764·64 }	4s			20981·7
4753·23 }	5			21032·1	4764·78	2			20981·1
4753·36 }				21031·5	4764·93	3			20980·5
4753·54	5			21030·7	4765·14	3 }			20979·5
4753·75	2			21029·8	4765·40	3 } b			20978·4
4753·99	4			21028·8	4765·54	3 }			20977·8
4754·10	2			21028·3	4765·78	3			20976·7
4754·52	5 }			21026·4	4765·95	3	1·41		20976·0
4754·68	5 }			21025·7	4766·30	4	1·42		20974·4
4754·90	5 }			21024·7	4766·53	6⊙			20973·4
4755·09	3 }			21023·9	4766·75	6			20972·4
4755·31	3			21022·9	4766·95	4n			20971·6
4755·48	2			21022·2	4767·29	2			20970·1
4755·58	2			21021·7	4767·40	2			20969·6
4755·73	3			21021·1	4767·54	2			20969·0
4755·85	2			21020·5	4767·73	3			20968·1
4756·00	3			21019·9	4767·99	2			20967·0
4756·12	3			21019·3	4768·18	2			20966·2
4756·30	4			21018·5	4768·33	4			20965·5
4756·52	4			21017·6	4768·59	4			20964·4
4756·82	4			21016·2	4768·71	2			20963·0
4756·97	3			21015·6	4769·03	3			20962·4
4757·11	3			21015·0	4769·16	2			20961·9
4757·30	3			21014·1	4769·35	2			20961·0
4757·47 }	4			21013·4	4769·48	3			20960·4
4757·54 }				21013·1	4769·90	2			20958·6
4757·75	4⊙			21012·1	4770·19	4			20957·3
4757·89	4			21011·5	4770·53	3			20955·8
4758·12	4			21010·5	4770·66 }	3			20955·3
4758·33	5⊙			21009·6	4770·93 }				20954·1
4758·56	5			21008·6	4771·14	4			20953·1
4758·95	5			21008·6	4771·39	2			20952·0
4759·05	5			21006·4	4771·56	4			20951·3
4759·37	5			21005·0	4771·67	4			20950·8
4759·50	5			21004·4	4771·85	4			20950·0
4759·83	3			21002·9	4772·10	4			20949·9
4759·99	3			21002·2	4772·37	3			20947·7
4760·32	6			21000·8	4772·76	2			20946·0
4760·57	5			20999·7	4773·08	3 } b			20944·6
4760·78	5			20998·8	4773·23	3 }			20944·0

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued*.

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}-$				λ+	$\frac{1}{\lambda}-$	
4773·39	3 } b	1·42	6·2	20943·3	4788·36	4	1·42	6·2	20877·8
4773·57*	4 }			20942·5	4788·56	2			20876·9
4773·86	3			20941·2	4788·90	4			20875·4
4774·08	5			20940·2	4789·23	5			20874·0
4774·35	4			20939·1	4789·60	4			20872·4
4774·68	4			20937·6	4789·89	2			20871·1
4774·93*	5			20936·5	4790·16	3			20869·9
4775·18 }	4			20935·4	4790·45 }	b†			20868·7
4775·27 }				20935·0	4790·73 }				20867·4
4775·60	4			20933·6	4790·94 }	2b			20866·5
4776·03	5			20931·7	4791·13 }				20865·7
4776·31	5			20930·5	4791·27	2			20865·1
4776·55	3			20929·4	4791·49	2			20864·1
4776·84	3			20928·1	4791·61	3			20863·6
4777·05	2			20927·2	4791·93	2			20862·2
4777·26	2			20926·3	4792·24	4			20860·9
4777·51	5			20925·2	4792·56	4			20859·5
4777·79	4			20924·0	4792·71	3			20858·8
4777·95	4			20923·3	4792·91	2			20857·9
4778·25	5			20922·0	4793·08	2			20857·2
4778·56	3			20920·6	4793·26	2			20856·4
4778·75	2			20919·8	4793·65	3			20854·7
4778·95	3			20918·9	4793·83	2			20853·9
4779·25	5			20917·6	4793·98	2			20853·3
4779·61	4			20916·0	4794·39	5 } b			20851·5
4779·73	4			20915·5	4794·77	5 }			20849·9
4779·95	4			20914·5	4795·01	3			20848·8
4780·04	3			20914·1	4795·48	2			20846·8
4780·24	4			20913·2	4795·63	2			20846·0
4780·61	3			20911·6	4795·78	2			20845·5
4780·85	4			20910·6	4796·03	4			20844·4
4781·68	4			20906·9	4796·33	5			20843·1
4781·96	5b			20905·7	4796·53	3			20842·2
4782·26	5b			20904·4	4796·68	2			20841·5
4782·76	2			20902·2	4796·88	2			20840·7
4783·25	3			20900·1	4797·17	2			20839·4
4783·76*	3			20897·9	4797·41	2			20838·4
4783·96	3			20897·0	4797·62	2			20837·5
4784·14	2			20896·2	4798·02	2			20835·7
4784·28	4			20895·6	4798·26	3			20834·7
4784·47	3			20895·8	4798·45	2			20833·9
4784·61	3			20894·1	4798·60 }	2†			20833·2
4784·88	3			20893·0	4798·83 }				20832·2
4785·25	4			20891·5	4799·05	3			20831·2
4785·56	2			20890·0	4799·31	3			20828·4
4785·78	2			20889·0	4799·71	3			20830·1
4786·04	2			20887·9	4800·18 }	3			20826·3
4786·35	3			20886·5	4800·27 }				20826·0
4786·63	3			20885·3	4800·56	3			20814·7
4786·74	2			20884·8	4800·74	2			20813·9
4786·92	3			20884·1	4800·90	3			20813·2
4787·07	3			20883·4	4801·00	2			20813·8
4787·44	3			20881·8	4801·24	3			20811·8
4787·94	3			20879·6	4801·44	3			20810·9
4788·07	3			20879·0	4801·67	2			20809·9

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4801·77	2	1·42	6·2	20809·5	4817·49	3	1·43	6·2	20751·5
4802·02	2	1·43		20808·4	4817·67	2			20750·7
4802·16	3			20807·8	4818·40*	3			20747·6
4802·50	3			20806·3	4818·59	2			20746·8
4802·72	3			20805·3	4818·78	3			20745·9
4803·16*	4			20803·4	4818·93	3			20745·3
4803·42*	3			20802·3	4819·10	2			20744·6
4803·68*	3			20801·2	4819·33	3			20743·2
4804·09	3			20799·4	4819·50	3			20742·8
4804·47	4			20797·7	4819·72	2			20741·9
4804·68	2			20797·8	4820·48	3		6·2	20738·6
4804·88	2			20796·0	4820·79	2		6·1	20737·3
4805·15	2			20794·8	4820·96	3			20736·6
4805·36	3			20793·9	4821·24	2			20735·4
4805·71	4			20792·4	4821·46	2			20734·5
4805·89	2			20791·6	4821·59	2			20733·9
4806·11	2			20790·6	4821·87	2			20732·7
4806·26	2			20790·0	4822·09	2			20731·8
4806·48	3			20789·0	4822·42	3			20730·4
4806·66	4			20798·3	4822·26	4			20729·3
4806·99	2			20796·8	4823·13*	3			20727·2
4807·61	3			20794·2	4824·23	3			20722·6
4807·70	3			20793·8	4824·60	2			20721·0
4807·95	4			20792·7	4824·79	2			20720·2
4808·40 }	4			20790·7	4825·06	2			20719·0
4808·49 }				20790·3	4825·25	2			20718·2
4808·73	3			20789·3	4825·49	2			20717·2
4808·97	3			20788·3	4826·02	2			20714·9
4809·26	2			20787·0	4826·22	2			20714·0
4809·80*	5s			20784·7	4826·48	2			20712·9
4810·16*	5s			20783·1	4826·65	2			20712·2
4810·53	3			20781·5	4826·85	2			20711·3
4810·92	3			20779·8	4826·98	2			20710·8
4811·27	4			20778·3	4827·38	3			20709·1
4811·56	4			20777·1	4827·75	2			20707·5
4811·77	2			20776·2	4828·09	2			20706·0
4812·02	2			20775·1	4828·23	2			20705·4
4812·30	4			20773·9	4828·44	2			20704·5
4812·39	2			20773·5	4828·64	2			20703·7
4812·55	4			20772·8	4829·10	4n			20701·7
4812·85	3			20771·5	4830·40	2			20696·1
4812·99	2			20770·9	4830·60	2			20695·3
4813·47	3n			20768·8	4831·33	2			20692·1
4813·79	3			20767·4	4831·47	2			20691·5
4813·94	2			20766·8	4831·77	3			20690·2
4814·21	3			20765·6	4832·16	2			20688·6
4814·45	4			20764·6	4832·36	3			20687·7
4814·66	2			20763·7	4832·94	2			20685·2
4814·84	4			20762·9	4833·51	3			20682·8
4815·17	3			20761·5	4833·99	2			20680·7
4815·61*	3			20759·6	4834·43*	2			20678·9
4816·01	4			20757·9	4834·90	3			20676·8
4816·30	3n			20756·6	4835·75	3			20673·2
4816·74	4			20754·7	4835·94	3			20672·4
4817·15	4			20753·0	4836·22	2	1·43		20671·2

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4836·44	3	1·44	6·1	20670·3	4848·65	3	1·44	6·1	20618·2
4836·72	2			20669·1	4848·81	4			20617·5
4836·91	2			20668·2	4848·91	4			20617·1
4837·25	2n			20666·8	4849·14	3			20616·1
4837·64	2n			20665·1	4849·32	4			20615·4
4838·00	3n			20663·6	4849·41	4			20615·0
4838·45	3n			20661·7	4849·62	3			20614·1
4838·96	3			20659·5	4849·79	4			20613·3
4839·94	2			20655·3	4849·91	4			20612·8
4840·24	3bn			20654·0	4850·12	3			20611·9
4840·44	3⊙			20653·2	4850·33	4			20611·1
4840·76	2			20651·8	4850·49	4			20610·4
4841·04	2⊙			20650·6	4850·66	3			20609·6
4841·44	2			20649·9	4850·88	4			20608·7
4841·80	2			20647·4	4851·00	4			20608·2
					4851·19	3			20607·4
					4851·43	4			20606·4
Group C	λ 4842–5041				4851·57	4			20605·8
4842·44	12			20644·6	4851·79	4			20604·8
4842·85				20642·9	4852·01	4			20603·9
4842·98				20642·2	4852·17	4			20603·2
4843·13				20641·7	4852·34	4			20602·5
4843·31				20640·9	4852·58	4			20601·5
4843·49				20640·2	4852·76	4			20600·7
4843·73	5			20639·1	4852·93	4			20600·0
4843·92	5			20638·3	4853·22	4			20598·8
4844·17	5			20637·3	4853·39	4			20598·1
4844·37	4			20736·4	4853·56	5			20597·3
4844·45	4			20636·1	4853·83	4			20596·2
4844·65	4			20635·2	4854·01	4			20595·4
4844·72	4			20634·9	4854·17	5			20594·7
4844·94	4			20634·0	4854·49	4			20593 4
4845·04	4			20633·6	4854·68	4			20592·6
4845·26	4			20632·6	4854·86	5			20591·8
4845·34	4			20632·3	4855·14	4			20590·6
4845·57	4			20631·3	4855·30	4			20590·9
4845·64	4			20631·0	4855·50	5			20589·1
4845·89	4			20629·9	4855·90	5			20587·4
4846·00	4			20629·5	4856·05	4			20586·8
4846·26	4			20628·4	4856·22	5			20586·0
4846·37	4			20627·9	4856·55	5			20584·6
4846·65	4			20626·7	4856·73	4			20583·9
4846·77	4			20626·2	4856·89	5			20583·2
4846·94	2			20625·5	4857·28	5			20581·5
4847·07	4			20624·9	4857·45	4			20580·8
4847·17	4			20624·5	4857·57	5			20580·3
4847·34	2			20623·8	4857·97	5	1·44	6·1	20578·6
4847·48	4			20623·2	4858·18	4			20577·7
4847·57	4			20622·8	4858·30	5			20577·2
4847·80	3			20621·8	4858·76	5			20575·3
4847·92	4			20621·3	4858·94	4			20574·5
4848·01	4			20620·9	4859·04	5			20574·1
4848·22	3			20620·0	4859·52	5			20572·1
4848·35	4			20619·5	4859·70	5			20571·3
4848·44	4			20619·1	4859·82	5			20570·8

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
4860·29	5	1·44	6·1	20568·8	4872·93	3	1·44	6·1	20515·4
4860·50	5			20567·9	4873·11	3	1·45		20514·7
4860·59	5			20567·5	4873·35	6			20513·7
4861·12	5			20565·3	4873·50*	6			20513·0
4861·33	4			20564·4	4873·72	2			20512·1
4861·41	5			20564·1	4873·90	3			20511·3
4861·92	4			20561·9	4874·03	3			20510·8
4862·14	6			20561·0	4874·20	2			20510·1
4862·24	4			20560·5	4874·41	6s }			20509·2
4862·77	6			20558·3	4874·54	4 } b			20508·7
4862·97	4			20557·5	4874·63	4 }			20508·3
4863·09	6			20557·0	4874·93	3			20507·0
4863·64	4			20554·6	4875·11	3			20506·3
4863·82	5			20553·9	4875·27	2			20505·6
4863·94	4			20553·4	4875·46	6			20504·8
4864·50	4			20551·0	4875·58	4			20504·3
4864·70	5			20550·1	4875·71	4			20503·7
4864·79	4			20549·8	4875·80	2			20503·3
4865·43	4			20547·1	4876·05	3			20502·3
4865·61	5			20546·3	4876·25	3			20501·5
4865·67	4			20546·0	4876·39	2			20501·5
4866·33	4			20543·3	4876·56	6			20500·1
4866·54	8			20542·4	4876·64	6			20499·8
4866·80	2			20541·3	4876·84	5			20499·0
4866·93	2			20540·7	4876·96	3			20498·5
4867·06	2			20540·2	4877·26	3			20497·2
4867·26	4			20539·3	4877·45	2			20496·4
4867·48	7			20538·4	4877·64	5			20495·6
4867·78 }	2†			20537·1	4877·75	6			20495·2
4868·03 }				20536·1	4877·98	4			20494·2
4868·05	4			20536·0	4878·20	3			20493·3
4868·42	7			20534·4	4878·54	3			20491·8
4868·63	2			20533·6	4878·79	6			20490·6
4868·77	2			20533·0	4878·90	6			20490·1
4868·88	2			20532·5	4879·15	5			20489·3
4869·08	2			20531·7	4879·35 }	3			20488·4
4869·26	4			20530·9	4879·54 }				20487·6
4869·37	4			20530·4	4879·91	6			20486·1
4869·45	6			20530·1	4880·07	7			20485·4
4869·69	3			20529·1	4880·32	4			20484·4
4869·82	3			20528·5	4880·56	3			20483·3
4870·06	2			20527·5	4880·72 }	3b			20482·7
4870·25	5			20526·7	4880·90 }				20481·9
4870·46	6			20525·8	4881·10	5			20481·1
4870·77	3			20524·5	4881·25	7			20480·5
4870·91	3			20523·9	4881·51	6			20479·4
4871·24	6			20522·6	4881·96	3n			20477·5
4871·48	6⊙			20521·5	4882·24	8			20476·3
4871·60	2			20521·0	4882·43	8			20475·5
4871·74	2			20520·4	4882·71	5			20474·3
4872·02	2			20519·3	4882·96	3bn			20473·3
4872·29	6⊙			20518·1	4883·45	6			20471·2
4872·46	6			20517·4	4883·60	5			20470·6
4872·61	2			20516·8	4883·70	5			20470·2
4872·77	2			20516·1	4883·98	4			20469·0

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4884·25	3	1·45	6·1	20467·9	4897·95	5	1·45	6·0	20410·7
4884·48	3			20466·9	4898·17	3			20409·8
4884·66	5s			20466·1	4898·52	3			20408·3
4884·84	4s			20465·4	4898·79	3			20407·2
4884·96	3			20464·9	4899·16	6			20405·7
4885·03	2			20464·6	4899·37	6			20404·8
4885·26	5⊙			20463·6	4899·94	3			20402·4
4885·87	6			20461·1	4900·24	5			20401·2
4886·08	6			20460·2	4900·34	2			20400·7
4886·22	5			20459·6	4900·59	5			20399·7
4886·51	4⊙			20458·4	4900·79	5			20398·9
4886·73	2			20457·5	4901·32	3			20396·7
4886·95	3			20456·6	4901·45	4			20396·1
4887·11	4			20455·9	4901·74	3			20394·9
4887·31	4			20455·0	4902·03	4			20393·7
4887·52	4			20454·2	4902·25	4			20392·8
4887·79	6			20453·1	4902·40	3			20392·2
4887·85	2			20452·8	4902·53	3			20391·6
4888·41	6			20450·4	4902·76	2			20390·7
4888·57	6s b			20449·8	4903·03	3			20389·5
4888·85	b			20448·6	4903·24	2			20388·7
4889·11	4s b			20447·5	4903·54	6			20387·4
4889·32	b			20446·6	4903·72	6			20386·7
4889·47	b			20446·0	4904·49	3			20383·5
4889·68	5s b			20445·1	4904·67	2			20382·7
4889·85	5			20444·4	4904·84	6			20382·0
4890·14	4			20443·2	4905·04	6			20381·2
4890·44	6			20442·0	4905·22	6			20380·4
4891·00	5			20439·6	4905·81	2			20378·0
4891·18	5			20438·9	4906·07	6			28376·9
4891·30	4			20438·4	4906·31	3			20375·9
4891·53	4			20437·4	4906·52	6s			20375·0
4891·77	4			20436·4	4906·71	6s			20374·2
4892·32	6			20434·1	4906·95	3	1·45		20373·3
4892·50	4			20433·3	4907·15	4	1·46		20372·4
4892·87	3			20431·8	4907·55*	3			20370·8
4893·14	4			20430·7	4907·89	2⊙			20369·4
4893·32	3			20429·9	4908·03	4s			20368·8
4893·64	5			20428·6	4908·21	6b^{v}			20368·0
4893·83	4			20427·8	4908·67	3n			20366·1
4894·10	3			20426·7	4909·18	3			20364·0
4894·29	4			20425·9	4909·34	3			20363·3
4894·56	3		6·1	20424·7	4909·55	6⊙			20362·5
4895·00	7		6·0	20423·0	4909·80	4			20361·4
4895·20	7			20422·2	4909·93	2			20360·9
4895·65	4			20420·3	4910·55	3			20358·3
4895·93	3			20419·1	4910·72	4⊙			20357·6
4896·08	3			20418·5	4911·11	5			20356·0
4896·24	2			20417·8	4911·36	4⊙			20355·0
4896·37	5			20417·3	4911·82	3			20353·0
4896·58	5			20416·4	4912·00	3			20352·3
4897·07	5			20414·4	4912·41	3			20350·6
4897·27	3			20413·5	4912·74	5			20349·2
4897·36	4			20413·2	4912·94	4			20348·4
4897·75	5			20411·5	4913·06	3			20347·9

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
4913·24	3	1·46	6·0	20347·2	4930·18	2	1·46	6·0	20277·2
4913·45	3			20346·3	4930·44	2			20276·2
4913·76	3			20345·0	4931·03	2			20273·7
4914·09	3			20343·6	4931·27	2			20272·7
4914·35	6			20342·6	4931·41	4			20272·2
4914·55	5			20341·7	4931·63	4			20271·3
4914·79	2			20340·7	4932·02	3			20269·7
4915·08	2			20339·5	4932·37	2			20268·2
4915·93	4			20336·0	4932·56	3			20267·5
4916·14	4			20335·2	4932·79	3			20266·5
4916·44	2			20333·9	4933·18	4			20264·9
4916·65	2			20333·0	4933·44	4			20263·8
4916·94	3			20331·8	4933·89	2			20262·0
4917·15	3			20331·0	4934·07	2			20261·2
4917·39	2			20330·0	4935·02	4			20257·3
4917·58	4			20329·2	4935·28	4			20256·3
4917·81	5			20328·2	4935·42	2			20255·7
4918·28	3			20326·3	4935·57	2			20255·1
4918·47	3			20325·5	4935·80	4			20254·1
4918·83	2			20324·0	4936·23	2			20252·4
4919·25	5			20322·3	4936·48	2			20251·3
4919·47	5			20321·4	4936·85	4			20249·8
4919·62	3			20320·8	4937·10	5			20248·8
4919·83	3			20319·9	4937·34	3			20247·8
4920·23	2			20318·2	4937·72	3			20246·3
4920·58	2			20316·8	4938·71	5			20242·2
4920·92	5			20315·4	4938·97	5			20241·1
4921·15	6			20314·4	4939·26	2			20239·9
4921·62	3			20312·5	4939·62	2			20238·5
4921·98	2			20311·0	4940·31	3			20235·6
4922·37	3			20309·4	4940·58	4			20234·5
4922·61	6			20308·4	4940·85	4			20233·4
4922·86	4			20307·4	4941·18	3			20232·1
4923·41	2			20305·1	4941·61	3			20230·3
4923·74	3			20303·8	4941·93	3	1·46		20229·0
4923·98	3			20302·8	4942·17	3	1·47		20228·0
4924·33	4			20301·3	4942·48	4			20226·8
4924·57	4			20300·3	4942·76	4			20225·6
4924·71	3			20299·8	4943·18	2			20223·9
4924·84	3			20299·2	4943·53	3			20222·5
4925·15	3			20297·9	4943·79	2			20221·4
4925·39	3			20297·0	4944·43	4			20218·8
4925·67	2			20295·8	4944·69	4			20217·7
4926·07	4			20294·2	4945·16	3			20215·8
4926·31	4			20293·2	4945·47	3			20214·5
4926·47	2			20292·5	4946·33	4			20211·0
4926·59	2			20292·0	4946·64	4			20209·7
4926·83	3			20291·0	4946·83	2			20209·9
4927·46	2			20288·4	4947·08	4n			20207·9
4927·81	4			20287·0	4947·55	3			20206·0
4928·05	5			20286·0	4948·34	4			20202·8
4928·30	4			20285·0	4948·56	4			20201·9
4929·26	2			20282·0	4948·80	3			20200·9
4929·57	5			20280·7	4949·19	3			20199·3
4929·83	5			20279·7	4949·60	3			20197·7

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
4950·32	5	1·47	6·0	20194·7	4978·03	4	1·48	5·9	20082·4
4950·56	5			20193·7	4978·38	4			20081·0
4951·24	3			20191·0	4980·09	2			20074·1
4951·63	2			20189·4	4980·30	3			20073·2
4951·94	3			20188·1	4980·47	2			20072·5
4952·29	4			20186·7	4980·66	3			20071·8
4952·59	4			20185·4	4982·17	2			20065·7
4953·71	3			20180·9	4982·53	3			20064·2
4953·94	2			20179·9	4982·89	3			20062·8
4954·33	4			20178·4	4984·16	2			20057·7
4954·64	4			20177·1	4984·54	2			20056·1
4955·42	4			20173·9	4984·86	3			20054·8
4955·77	2			20172·5	4985·19	3			20053·5
4956·39	4			20170·0	4986·22	2			20049·4
4956·67	4			20168·8	4986·55	2			20048·0
4957·24	2			20166·5	4987·18	3			20045·5
4958·47	4			20161·5	4987·55	3			20044·0
4958·77	4			20160·3	4988·30	2			20041·0
4959·03	2			20159·2	4988·67	2			20039·5
4959·37	2			20157·8	4989·62	3			20035·7
4959·72	2			20156·4	4989·90	3			20034·6
4960·55	4			20153·1	4990·35	2			20032·8
4960·86	4			20151·8	4990·75	2			20031·2
4961·23	2			20150·3	4991·90	3			20026·5
4961·55	2			20149·0	4992·27	3			20025·1
4961·86	2			20147·7	4992·50	2			20024·1
4962·32	2			20145·9	4992·85	2			20022·7
4962·69	5			20144·4	4994·15	3			20017·5
4963·00	5			20143·1	4994·62	3			20015·6
4963·38	2			20141·6	4996·68	3			20007·4
4964·11	2			20138·6	4997·07	3			20005·8
4964·57	2			20136·7	4999·12	2			19997·6
4964·81	3			20135·8	4999·45	2			19996·3
4965·13	3⊙			20134·5	5001·17	2			19989·4
4966·48	2			20129·0	5001·57	3			19987·8
4966·80	3			20127·7	5001·94	3			19986·3
4966·97	3			20127·0	5003·34	2			19980·7
4967·27	3			20125·8	5003·77	2			19979·0
4968·32	2			20121·5	5004·06	3			19977·9
4968·73	2			20119·9	5004·41	3			19976·5
4969·17	3			20118·1	5005·56	2			19971·9
4969·49	3			20116·8	5006·00	2			19970·1
4970·30	2		6·0	20113·5	5006·54	3			19968·0
4970·62	2		5·9	20112·3	5006·91	3			19966·5
4971·20	2			20110·0	5007·87	2			19962·7
4971·38	3			20109·2	5008·27	2			19961·1
4971·71	3			20107·9	5009·06	3			19957·9
4972·24	2			20105·8	5009·43	3			19956·4
4972·57	2			20104·4	5010·10	2			19953·8
4973·58	4			20100·3	5010·49	2			19952·2
4973·92	4			20098·9	5011·59	3			19947·8
4974·24	2			20097·7	5011·94	3			19946·4
4974·58	2			20096·3	5012·38	2			19944·7
4975·82	4			20091·3	5012·80	2	1·49	5·9	19943·0
4976·13	4	1·47		20090·0	5014·12	2			19937·8

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
5014·50	2	1·48	5·9	19936·3	5085·38	2	1·51	5·8	19658·4
5014·67	2			19935·6	5085·56	2			19657·7
5015·12	2			19933·8	5085·83	2			19656·7
5016·73	2			19927·4	5086·01	2			19656·0
5017·00	2			19926·3	5086·31	2			19654·8
5017·08	2			19926·0	5086·47	2			19654·2
5017·45	2			19924·5	5086·78	2			19653·0
5019·29	2			19917·2	5086·97	2			19652·3
5019·41	2			19916·8	5087·29	2			19651·0
5019·67	2			19915·7	5087·46	2			19650·4
5019·79	2			19915·2	5087·81	2			19649·0
5021·94 }	3			19906·7	5087·98	2			19648·4
5022·34 }				19905·1	5088·33	2			19647·0
5024·54 }	3			19896·4	5088·53	2			19646·2
5024·96 }				19884·8	5088·88	2			19644·9
5027·21 }	2			19885·8	5089·08	2			19644·1
5027·62 }				19884·2	5089·27	2			19643·4
5029·86 }	2			19875·4	5089·45	2			19642·7
5030·32 }				19873·5	5089·63	2			19642·0
5032·55 }	2			19864·7	5089·81	2			19641·3
5033·05 }				19862·7	5090·01	2			19640·5
5035·30 }	2			19863·9	5090·24	2			19639·6
5035·76 }				19862·1	5090·43	2			19638·9
5038·07 }	3			19843·0	5090·63	2			19638·1
5038·50 }				19841·3	5090·84	2			19637·3
5040·88 }	3			19831·9	5091·01	2			19636·7
5041·26 }				19830·4	5091·22	2			19635·9
					5091·47	2			19634·9
Group λ	5079–52	10			5091·64	2			19634·2
					5091·89	3			19633·3
5079·52	8	1·50	5·8	19681·1	5092·09	3			19632·5
5079·95	2			19679·4	5092·25	3			19631·9
5080·11	2	1·50		19678·8	5092·52	3			19630·8
5080·20	2	1·51		19678·5	5092·76	3			19629·9
5080·44	2			19677·5	5092·92	3			19629·3
5080·65	2			19676·7	5093·20	3			19628·2
5080·84	2			19676·0	5093·43	3			19627·3
5081·05	2			19675·2	5093·58	3			19626·8
5082·11				19671·1	5093·90	3			19625·5
5082·23				19670·6	5094·12	3			19624·7
5082·41				19669·9	5094·25	3			19624·2
5082·54				19669·4	5094·59	3			19622·9
5082·71	2			19668·7	5094·82	3			19622·0
5082·87	2			19668·1	5094·94	3			19621·5
5083·06	2			19667·4	5095·29	2			19620·2
5083·21	2			19666·8	5095·54	4			19619·2
5083·40	2			19666·1	5095·66	3			19618·7
5083·75	2			19664·7	5096·02	2			19617·3
5083·91	2			19664·1	5096·30	4			19616·3
5084·14	2			19663·2	5096·41	2			19615·8
5084·30	2			19662·6	5096·79	2			19614·4
5084·54	2			19661·7	5097·05	4⊙			19613·4
5084·70	2			19661·0	5097·16	2⊙			19613·0
5084·93	2			19660·1	5097·58	3			19611·3
5085·11	2			19659·4	5097·84	5			19610·3

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
5098·35	2	1·51	5·8	19608·4	5111·27	2	1·51	5·8	19558·8
5098·62	5			19607·5	5111·52	4			19557·8
5099·15	2			19605·3	5111·69	2			19557·2
5099·38	5			19604·4	5112·05				19555·8
5100·00	2			19602·0	5112·17	5			19555·4
5100·25	5			19601·1	5112·28				19554·9
5100·79	2			19599·0	5112·59	4			19553·8
5101·07	5			19597·9	5112·81	2			19552·9
5101·67	2			19595·6	5113·21	5			19551·4
5101·92	4			19594·7	5113·37	5			19550·8
5102·32	12			19592·1	5113·79	3			19549·2
5102·84	6			19591·1	5114·00	2			19548·4
5103·06	2			19590·3	5114·25	2			19547·4
5103·23	2			19589·6	5114·42	5			19546·8
5103·41	3			19588·9	5114·65	2	1·51		19545·9
5103·61	4			19588·2	5115·02	4	1·52		19544·5
5103·77	4			19587·6	5115·29	3			19543·4
5104·03	2			19586·6	5115·50	2			19542·6
5104·24				19585·8	5115·68	3			19541·9
5104·36				19585·3	5115·91	2			19541·1
5104·49				19584·8	5116·34	5			19539·4
5104·64	3			19584·2	5116·60	5			19538·4
5104·91	2			19583·2	5116·98	5			19537·0
5105·05	2			19582·6	5117·26	2			19535·9
5105·18	2			19582·1	5117·50	2			19535·0
5105·35	3			19581·5	5117·69	5			19535·3
5105·53	3			19580·8	5117·98	2			19533·2
5105·80	2			19579·8	5118·11	2			19532·7
5105·99	2			19579·0	5118·38	4			19531·6
5106·18	2			19578·3	5118·62	4			19530·7
5106·32	4			19577·8	5118·79	2			19530·1
5106·50	4			19577·1	5119·15	4b			19528·7
5106·68	2			19576·4	5119·42	2			19527·7
5106·88	2			19575·8	5119·77	4			19526·3
5107·08	2			19574·9	5119·90	5			19525·8
5107·25	4			19574·2	5120·15	3			19524·9
5107·44	4			19573·5	5120·51	4			19523·5
5107·68	2			19572·6	5120·64				19523·0
5107·85	3			19571·9	5120·90	4			19522·0
5108·10	2			19570·9	5121·09	3			19521·3
5108·22	4			19570·5	5121·28	4			19520·6
5108·32	2			19570·1	5121·41	4			19520·1
5108·52	3			19569·3	5121·69	3			19519·0
5108·70	3			19568·6	5122·06	5			19517·6
5108·97	2			19567·6	5122·21	5			19517·0
5109·17	4			19566·8	5122·50	3			19515·9
5109·32	2			19566·3	5122·86	4			19514·5
5109·47	3			19565·7	5122·98	4			19514·1
5109·64	2			19565·0	5123·26	3			19513·0
5109·91	2			19564·0	5123·47	9			19512·2
5110·15	4			19563·1	5123·57				19511·8
5110·28	2			19562·6	5123·79*	6			19511·0
5110·46	3			19561·9	5124·15	3			19509·6
5110·95	2			19560·0	5124·44	4s			19508·5
5111·15	4			19559·3	5124·64	5s			19507·8

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
5125·03	4s	1·52	5·8	19506·3	5137·78	2	1·52	5·8	19457·9
5125·28	3			19505·3	5138·00	2			19457·0
5125·47	3			19504·6	5138·32	3			19455·8
5125·68	3			19503·8	5138·67	4			19454·5
5125·89	3			19503·0	5138·85	4			19453·8
5126·20	3			19501·8	5139·06	3			19453·0
5126·30	3			19501·4	5139·40	3			19451·7
5126·47	2			19500·8	5139·74	4			19450·4
5126·60	2			19500·3	5139·92	3			19449·7
5126·77	2			19499·7	5140·19	3			19448·7
5126·92	3			19499·1	5140·46	4			19447·7
5127·14	4			19498·2	5140·83	5			19446·3
5127·62*	2			19496·4	5141·02	3			19445·6
5127·91	3			19495·3	5141·18	2			19444·0
5128·17	3			19494·3	5141·60	5			19443·4
5128·34	3			19493·7	5141·84	2			19442·5
5128·54	2			19492·9	5142·12	2			19441·4
5128·71	2			19492·3	5142·33	2			19440·6
5128·83	2			19491·8	5142·53	2			19439·9
5128·95	2			19491·4	5142·74	2			19439·1
5129·15	3			19490·6	5143·08	6			19437·8
5129·46	3			19489·4	5143·27	8			19437·1
5129·71	3			19488·5	5143·48	3			19436·3
5129·95	3			19487·6	5143·89	4			19434·7
5130·17	3			19486·7	5144·20	4			19433·6
5130·43	3			19485·7	5144·38	4			19432·9
5130·69	4			19484·8	5144·52	2			19432·4
5130·89	4			19484·0	5144·77	4			19431·4
5131·12	2			19483·1	5145·04*	2			19430·4
5131·38	3			19482·1	5145·26*	2			19429·6
5131·61	3			19481·3	5145·48	5 b			19428·7
5131·82*	3			19480·5	5145·74	b			19427·7
5132·04	3			19479·6	5145·95*	4			19427·0
5132·40	3			19478·3	5146·25	6			19425·8
5132·57	2			19477·6	5146·48	3			19425·0
5132·71	2			19477·1	5146·73	4			19424·0
5132·90	3			19476·4	5146·92	2			19423·3
5133·42*	4			19474·4	5147·10	2			19422·6
5133·57	3			19473·8	5147·28	2			19421·9
5133·73	3			19473·2	5147·45	b			19421·3
5133·99	4			19472·2	5147·71	4 b			19420·3
5134·27	2			19471·2	5147·93	6			19419·5
5134·53	4			19470·2	5148·07	2			19419·0
5134·67	4			19469·6	5148·43	3			19417·6
5134·91	3			19468·7	5148·82	5	1·52		19416·1
5135·13	4			19467·9	5148·97	4	1·53		19415·6
5135·49	4			19466·6	5149·14	4			19414·9
5135·74	4			19465·6	5149·26	4			19414·5
5136·06	3			19464·4	5149·70	3			19412·8
5136·28	2			19463·5	5150·12	3			19411·2
5136·55	2			19462·5	5150·60	3			19409·4
5136·75	3			19461·8	5150·77	2			19408·8
5137·07	3			19460·5	5151·34	2			19406·6
5137·39	3			19459·3	5151·55	4			19405·8
5137·60	5			19458·5	5151·68	2			19405·3

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		λ+	$\frac{1}{\lambda}$−				λ+	$\frac{1}{\lambda}$−	
5152·38*	3	1·53	5·8	19402·7	5165·97	4b	1·53	5·7	19351·7
5152·58	5			19401·9	5166·26	3			19350·7
5152·85	3			19400·9	5166·72	4			19348·9
5153·04	4			19400·2	5166·89	2			19348·3
5153·60	4br			19398·1	5167·10*	2			19347·5
5153·85	4			19397·2	5168·32	4			19342·9
5153·99	2			19396·6	5168·79	4			19341·2
5154·11	2			19396·2	5169·19	5			19339·7
5154·30	3			19395·5	5169·49	2			19338·6
5154·50	3			19394·7	5169·78	4			19337·5
5154·80	2			19393·6	5170·22	4			19335·8
5155·16	4 b			19392·2	5170·37				19335·3
5155·42*	6			19391·3	5170·67	5n			19334·1
5155·98	4			19388·1	5170·93	2			19333·2
5156·25	2			19388·1	5171·30	2			19331·8
5156·45	6			19387·4	5171·57	4			19330·8
5156·77	b			19386·2	5172 09	2			19328·8
5157·02*	4			19385·2	5172·28	2			19327·1
5157·25	4			19384·4	5173·05	2			19325·2
5157·47	3			19383·5	5173·26	2			19324·7
5157·71	3			19382·6	5173·41	2			19323·9
5157·84	3			19382·2	5173·57	2			19323·3
5157·99	3			19381·6	5173·71	2			19322·8
5158·25	4b			19380·6	5174·03	4			19321·6
5158·53				19379·6	5174·32	3			19320·5
5158·71	2		5·8	19378·9	5174·63	3			19319·3
5159·06	4		5·7	19377·7	5174·79	2			19318·7
5159·32	4			19376·7	5175·13	3			19317·5
5159·53	2			19375·9	5175·27	4			19317·0
5159·71	2			19375·2	5175·53	4b			19316·0
5159·90	2			19374·5	5175·80	4			19315·0
5160·07*	2			19373·9	5175·94	2			19314·5
5160·35	5b			19372·8	5176·29	4			19313·2
5160·60	5			19371·9	5176·50	4b			19312·4
5160·70	3			19371·5	5176·62	2			19311·9
5161·00	4b			19370·4	5176·80	2			19311·3
5161·18				19369·7	5177·23	5b			19309·6
5161·41				19368·8	5177·51	5b			19318·6
5161·67	5			19367·9	5177·78	5b			19317·6
5161·80	5			19367·5	5178·06	3			19316·6
5162·05	6			19366·4	5178·18	4			19316·1
5162·77	5b			19363·7	5178·44*	4			19315·1
5163·19	2			19362·2	5179·04	5			19312·9
5163·36	5b			19361·5	5179·17	2			19312·4
5163·56				19360·8	5179·40	5b			19311·6
5163·66	2			19360·4	5179·72	5			19310·4
5163·80	2			19359·9	5179·94	2			19309·5
5163·94	2			19359·4	5180·24	4bn			19308·4
5164·09	2			19358·8	5180·50	3			19297·6
5164·33*	3			19357·9	5180·97	4			19295·7
5164·60*	4			19356·9	5181·27	5			19294·6
5164·88	4s			19355·8	5181·59	3			19293·4
5165·07	3			19355·1	5181·71	3			19292·9
5165·35	2			19354·1	5181·99	3s			19291·9
5165·67	3b			19352·9	5182·31	3			19290·7

ALUMINIUM OXIDE (ARC SPECTRUM)—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency	Wave-length	Intensity and Character	Reduction to Vacuum		Oscillation Frequency
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
5182·51	3	1·53	5·7	19290·0	5196·32	3	1·54	5·7	19238·7
5182·92	3 b			19288·4	5196·74	3			19236·1
5183·36	3	1·53		19286·8	5197·14	2			19235·6
5184·14	3	1·54		19283·9	5197·30	3			19235·1
5184·31	3			19283·3	5197·67*	4b			19233·7
5184·50	3			19282·6	5198·04	2			19232·3
5184·65	3			19282·0	5198·49	2			19230·7
5184·77	3			19281·6	5198·75	2			19229·7
5185·03	3			19280·6	5198·96*	2			19228·9
5185·30	2			19279·6	5199·37	2			19227·4
5185·54				19278·7	5199·77	3			19225·9
5185·88	3 b			19277·4	5200·14	3			19224·5
5186·17				19276·4	5200·31	3n			19223·9
5186·46	3			19275·3	5200·55	2			19223·0
5186·63	4			19274·6	5200·79	2			19222·1
5186·99	4			19273·3	5201·01	2			19221·3
5187·38	5			19271·9	5201·15	2			19220·8
5187·76	3			19270·4	5201·43	3n			19219·8
5188·09	4			19269·2	5201·61*	n			19219·1
5188·42				19268·0	520·.82	2			19218·3
5189·07	3			19261·6	5202·12	2			19217·2
5189·28	3			19264·8	5202·34	2			19216·4
5189·47	3			19264·1	5202·80	3			19214·7
5189·81	3			19262·8	5202·91				19214·3
5190·01	2			19262·1	5203·20	2			19213·2
5190·22	3			19261·3	5203·40	3			19212·5
5190·43	3			19260·5	5303·61	3			19211·7
5190·73	5			19259·4	5203·79	2			19211·1
5191·10	4			19258·0	5203·92	2			19210·6
5191·21				19257·6	5204·09	2			19210·0
5191·51				19256·5	5204·22	2			19209·5
5192·03	3 b			19254·6	5204·48	3			19208·5
5192·40	5			19253·2	5205·19	3			19205·9
5192·52	5⊙			19252·8	5205·40	2			19205·1
5192·79	5b			19251·8	5205·61	2			19204·3
5193·08	4			19250·7	5206·55	3			19200·9
5193·62	2			19248·7	5206·75	3			19200·1
5193·98*	2			19247·3	5206·97	3			19199·3
5194·16	3			19246·7	5207·62*	3			19196·9
5194·33	3			19246·1	5207·92	2			19195·8
5194·56	3			19245·2	5208·09	2			19194·2
5194·83	3			19244·2	5208·39	2			19194·1
5195·21	2n			19242·8	5208·83	3			19192·5
5195·40	2			19242·1	5209·46	4bn			19190·1
5195·62	2			19241·3	5209·98	3			19198·2
5196·06	3			19239·6	5210·28	3			19197·1

Sixth Report of the Committee, consisting of Professor W. A. Tilden, Professor H. McLeod, Mr. S. U. Pickering, Professor W. Ramsay *and* S. Young, *and* Dr. A. R. Leeds, *and* Dr. W. W. J. Nicol (*Secretary*), *appointed for the purpose of reporting on the Bibliography of Solution.*

The Committee report that considerable progress has been made during the past year. One new journal has been completely searched, and the others have been brought up to date. The work has so far advanced that the question of publication will soon have to be considered. The titles already collected now number over 1,200, including cross references, and are drawn from the leading scientific journals at home and abroad. It will perhaps be desirable to publish a first instalment, as the subject of Solution is now attracting so much attention that such a bibliography would be of great use. The Committee desire reappointment.

Sixth Report of the Committee, consisting of Professor W. A. Tilden, Professor W. Ramsay, *and* Dr. W. W. J. Nicol (*Secretary*), *appointed for the purpose of investigating the Nature of Solution.* (*Drawn up by* Dr. Nicol.)

I. *The Atomic Volumes of Carbon and Hydrogen in Organic Substances when in Dilute Solution.*

In 1883 it was observed that the molecular volumes of the sodium salts of formic, acetic, and butyric acid showed in dilute solution an approximately constant difference, giving 14·3 as the volume of the group CH_2 (Nicol, 'Phil. Mag.,' August, 1883, p. 131).

This point appeared worthy of further examination, inasmuch as, if dissolved substances are under comparable conditions when the solution is sufficiently dilute, as seems most probable from a consideration of the physical properties of such dilute solutions, then the apparent molecular volumes in dilute solution could be compared in the same way as the molecular volumes at the boiling-point, and thus the atomic volumes of the various elements could be determined with greater ease and certainty than at the boiling-point.

A series of preliminary experiments with the commoner compound ethers have been completed, the results of which will shortly be published, and these are so encouraging that the Committee have decided to go fully into the subject, and as the preparation, purification, and analysis of a sufficiently large number of compounds for the purpose of this research is necessarily long and tedious, the Committee will be glad to receive the assistance of members of Section B. who have suitable compounds, the composition of which is guaranteed by analysis. Such substances must be soluble in water, alcohol, benzol, xylol, ether, or chloroform. The secretary will gratefully acknowledge the receipt of specimens (three to five grams) sent to him at Mason College, Birmingham.

II. *Molecular Volume of Iodine in Solution.*

It is well known that the colour of solutions of iodine varies with the nature of the solvent from dark brown in the case of aqueous solution of potassium iodide, through red in benzol to violet in the case of carbon disulphide.

From the colour of the last-named solution it has generally been assumed that in it the iodine molecule is diatomic, as in the state of gas. Within the last few years several attempts have been made to ascertain what is the composition of the iodine molecule in various solvents, the method employed being that of Raoult, depending on the effect of the dissolved iodine on the vapour pressure of the solvent.

The Committee have commenced the examination of this subject from the standpoint of the apparent molecular volume of iodine in various solvents, and considerable progress has been made with the work. Aqueous potassium iodide, alcohol, ether, chloroform, benzol, xylol, and carbon disulphide having been examined, it is intended to considerably extend this list of solvents, and the Committee hope that they will be in a position to report fully on this subject to the next meeting of the Association, as they intend also to fully examine the point by the method of vapour pressures.

The Committee desire reappointment without grant.

Report (provisional) of a Committee, consisting of Professor H. E. ARMSTRONG, Professor W. R. DUNSTAN, Mr. C. H. BOTHAMLEY, *and* Mr. W. A. SHENSTONE (*Secretary*), *appointed to investigate the formation of Haloids from pure materials.* (*Drawn up by* Mr. W. A. SHENSTONE.)

DURING the past year two papers have been read before the Chemical Society on subjects connected with the work undertaken by the Committee.[1]

The results of further experiments with mercury and chlorine tend to confirm the opinion expressed in a previous report that the interaction of these two elements is greatly influenced by the presence of one or more other substances, and they show that water is almost certainly one of these active substances.

Up to the present *pure* chlorine has not been obtained. But W. A. Shenstone and C. R. Beck have recently found that by igniting platinic chloride in excess of hydrochloric acid platinous chloride may be obtained in such a condition that the chlorine liberated from it by ignition in vacuo is considerably more free from impurities than the product of igniting platinous chloride prepared in the ordinary way, and they think it possible that by this method pure chlorine may perhaps ultimately be obtained.

They have also found that liquefied chlorine, which usually contains a

[1] Platinous Chloride as a Source of Chlorine, *Journ. Chem. Soc.*, 1892, p. 445. The Adhesion of Mercury to Glass in the Presence of Halogens, *Journ. Chem. Soc.*, 1892, p. 452.

small proportion of hydrogen chloride, but is almost free from other impurities, can be purified to some extent by fractional evaporation.

Messrs. Shenstone and Beck have been occupied with the purification of phosphoric oxide, and have succeeded in preparing several samples of that substance in a crystalline state, and free from the lower oxides, by a process of oxidation with subsequent fractional sublimation of the oxidised product.

Some experiments have also been made with hydrogen chloride and oxygen, the results of which decidedly suggest that the interaction of these bodies in the dry state is dependent upon either the relative masses in which they are present or on the pressure at which they act. Mr. Shenstone proposes to repeat and to extend what has been done in this direction.

The Committee desire to be reappointed, and ask that a grant of 20*l.* may be made to them.

Report (provisional) of a Committee, consisting of Professor H. McLeod, Professor W. Ramsay, Mr. W. A. Shenstone (*Secretary*), *and* Mr. J. Tudor Cundall, *appointed to investigate the Influence of the Silent Discharge of Electricity on Oxygen and other Gases.*

The Committee are glad to be able to report that the work undertaken is proceeding in a satisfactory manner. After a year of continuous work, in which they have had the assistance of Mr. Martin Priest, the fundamental difficulties of the research have apparently been overcome, and several interesting observations have been made.

As, however, only a small part of the work has yet been done, they desire to defer presenting a detailed report till the next meeting of the Association.

The Committee, therefore, ask to be reappointed.

Report (provisional) of the Committee, consisting of Professor T. E. Thorpe, Professor J. J. Hummel (*Secretary*), Dr. W. H. Perkin, Professor W. J. Russell, Captain W. de W. Abney, *and* Professor W. Stroud, *on the Action of Light upon Dyed Colours.* (*Drawn up by* Professor J. J. Hummel.)

As mentioned in the last report, it was decided to compare first the fastness to light of the various *red* colouring matters. During the past year wool and silk patterns have been dyed with the technical products, and are now being exposed to light. The results, however, will not be ready till the next meeting of the Association, when both dyed and exposed patterns will be exhibited.

The grant of 10*l.* voted at the last Meeting has been more than expended in the erection of an additional exposing case, and in the purchase of a colorimeter, and also for books in which to mount the dyed and faded patterns.

The Committee desire to be reappointed, with the addition of Professor Meldola as a member, and request that a further sum of 5*l.* be granted to cover a small sum still due to the Secretary.

Report of the Committee, consisting of Sir J. Lowthian Bell, Professor P. Phillips Bedson (*Secretary*), Mr. Ludwig Mond, Professor Vivian B. Lewes, Professor E. Hull, Mr. J. W. Thomas, *and* Mr. H. Bauerman, *for inquiring into the Proximate Constituents of the various kinds of Coal.*

The bibliography of the subject which is in course of preparation is not yet completed. Experimental work is still in progress. The Committee ask to be reappointed, and hope to present a report next year.

Eighteenth Report of the Committee, consisting of Professor Hull (Chairman), Rev. Dr. H. W. Crosskey, Sir D. Galton, Messrs. J. Glaisher, Percy Kendall, Professor G. A. Lebour, E. B. Marten, G. H. Morton, W. Pengelly, J. Plant, Professor J. Prestwich, Messrs. I. Roberts, Thos. S. Stooke, G. J. Symons, W. Topley, Tylden-Wright, E. Wethered, W. Whitaker, *and* De Rance (*Secretary*), *appointed for the purpose of investigating the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Waters supplied to various Towns and Districts from these Formations.* (*Drawn up by* C. E. De Rance, *Reporter.*)

Since your reporter was appointed at the initiation of your Committee in 1872 he has received most valuable assistance from past and present members of the Committee in preparing the annual report, both as regards original observations made by them, original data collected from others by them, and by general hints and suggestions received from them. As regards the first two heads, many valuable communications have been too important to absorb into the general report, and have been given in separate appendices under the individual member's name. But your reporter is compelled to point out that the arrangement by which a member of the Committee took personal charge of a portion of England and Wales, which he instituted with a considerable measure of success in 1873, has year by year become less operative, and each succeeding annual report has contained less and less matter contributed by the Committee. The last communication received was in 1889, and is embodied in the fifteenth report. Since then your reporter has had no assistance from your Committee, and the sixteenth, seventeenth, and the present eighteenth reports have been wholly compiled from information collected by him and subsequently approved by the Committee at their annual meeting without alteration.

Under these circumstances your reporter has reluctantly come to the opinion that it is unadvisable to continue to issue reports under the high authority of a committee of enquiry of the British Association which are in reality the work of one person, for whose accuracy or otherwise the Committee (and indirectly the Association) are made responsible; reports which, however carefully prepared from trustworthy information from all parts of England and Wales, cannot possibly have the same value as when each local detail received can be checked by a local representative of the Committee, as was the case when your reporter first divided the country into districts, in each of which your Committee had an able representative.

These results have been brought about by various causes: (1) Losses by death, including Mr. Binney, F.R.S., Professor Harkness, F.R.S., Mr. Mylne, F.R.S., Mr. Molyneux, F.G.S.

(2) Losses through illness, including Professor Prestwich, F.R.S., Dr. Crosskey, F.G.S., Mr. Plant, F.G.S., Mr. Pengelly, F.R.S.

(3) Losses through change of residence and other causes, including Sir Frederick Bramwell, F.R.S., Mr. I. Roberts, F.R.S., Mr. Howell, F.G.S., and other able observers.

(4) Losses through members of the Committee contributing the information they have collected to the local societies, where they happen to live, and where the matter is locally printed, and which, in the opinion of your reporter, is the chief cause of the present dearth of information communicated by them to your reporter; for probably at no time were our underground sources of water supply being more constantly tapped, and at no time were boring contractors more willing to give thoroughly intelligent accounts of the work carried out by them.

Local publication has the advantage of giving the information quickly to the local district, where it is of direct use for matters of detail, to those on the spot, but is nearly useless for general reference and study, as local transactions of this class are constantly found to be absent from public libraries, while their publication and concentration in the annual volume of the British Association have been of great value for nearly twenty years, and have largely given an incentive to the use of underground water by pointing out its purity on the one hand and the absence of law costs to obtain it on the other. Before finally closing the enquiry your reporter suggests and your Committee approve that it would be advisable to publish in a connected form the varied information given in the past eighteen reports. In many of them the information is given in a more or less crude form, and the details of borings are given from year to year as they progressed in depth, and details of one set of works are carried on through several reports, and many of these are out of print.

It is therefore suggested that the Committee be reappointed with the usual grant of 5*l.*; that the Secretary be requested to draw up a final report embodying the whole of the facts obtained classified in counties; that it is advisable that the report in question should be issued and sold as a separate publication. It would be with peculiar fitness that your Committee should meet and present its final report, after its twenty years' labours, at Nottingham, which rejoices in a magnificent supply of the purest water derived from underground sources.

Valuable information has been received by your reporter since the last meeting from Dr. Parsons, of the Local Government Board; Messrs.

Mather and Platt, of Salford Iron Works; Messrs. Timmins, of Runcorn; the Salt Union, the United Alkali Trust, and others; but in view of the course suggested to avoid repetition, it appears most desirable to defer publication until next year should the Committee be reappointed.

Report of the Committee, consisting of Mr. J. W. Davis (*Chairman*), Rev. E. Jones (*Secretary*), Drs. J. Evans *and* J. G. Garson, *and* Messrs. W. Pengelly, R. H. Tiddeman, *and* J. J. Wilkinson, *appointed to complete the investigation of the Cave at Elbolton, near Skipton, in order to ascertain whether Remains of Palæolithic Man occur in the Lower Cave Earth.* (*Drawn up by* Rev. E. Jones.)

The exploration of this interesting cave was continued from the month of September 1891 to January last. The work excavated and examined has been extensive and a much lower level reached, but no new features of any value have been obtained. The difficulty and expense of working increase with the depth. Large blocks of stone and a stalagmitic floor two to three feet in thickness were broken up by the aid of gunpowder. The fissure is now fifty-five feet in depth from what was the floor of the chamber when the cave was discovered. It has narrowed considerably, being now only four to six feet in thickness.

At the west end of the fissure the material continues to be crowded with bones of Alpine hares and a few bones of bears and foxes, but the rest of the fissure is now barren, and is composed of soft adhesive clay resting on a layer of sand and gravel. This seems to indicate that we are near the bottom of the fissure and pothole, and that our work will be finished when this is reached.

The age of these lower deposits has yet to be ascertained. No bones of man, or of the horse or dog, animals domesticated by Neolithic men, have been found in them, while the bones of bear, absent in the upper layer, are abundant in the lower. The red deer and boar are found in both layers, but the reindeer only in the clay layer. Angular pieces of limestone are imbedded in the clay, but no boulders or scratched stones have been found in it.

The whole deposit is post-Glacial, but a great length of time must have intervened before Neolithic man dwelt in the cave and buried his dead there. The accumulation of forty feet of ossiferous material with a series of stalagmitic floors some three feet thick before the advent of the Neolith must represent a long period. No indications of Palæolithic man have been found.

The 'finds' require tabulating; many bones are still undetermined, and various abnormal bones, both human and animal, should be noted. The Committee desire therefore to be reappointed to prepare a final report, but do not apply for a grant.

Twentieth Report of the Committee, consisting of Professor J. Prestwich, Dr. H. W. Crosskey, Professors W. Boyd Dawkins, T. McK. Hughes, *and* T. G. Bonney *and* Messrs. C. E. De Rance, P. F. Kendall, W. Pengelly, J. Plant, *and* R. H. Tiddeman, *appointed for the purpose of recording the Position, Height above the Sea, Lithological Characters, Size, and Origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.* (*Drawn up by* Dr. Crosskey, *Secretary.*)

The researches of this Committee have been carried on during the past year with the assistance of the Yorkshire Boulder Committee — the Glacialists' Association (formerly the N.W. of England Boulder Committee, and whose contributions are marked *)—and several independent observers.

In previous reports the facts obtained by an exhaustive survey of the erratics of the Midland Counties have been classified, and a series of valuable results has thus been established.

It has not as yet been possible to extend the same kind of treatment to other districts on account of the constant accumulation of new material, such as that of which the report of this year contains fresh instalments.

The facts discovered are, however, rapidly showing that they are capable of orderly arrangement, and it cannot be doubted that the distribution and grouping of the erratic blocks of Great Britain will throw light on some of the most intricate questions of Glacial Geology.

The following reports have been received :—

The Yorkshire Boulder Committee.

Chairman : Professor L. C. Miall, *F.R.S.*, *F.G.S.*, *F.L.S.*, Yorkshire College, Leeds.

The Yorkshire Boulder Committee have comparatively few erratic blocks to report this year, nearly all the known examples having been previously recorded. This being the case, they have been at liberty to make important advances in their methods of research and to devise new modes of operation.

During the year their attention has been mainly given to maturing a scheme for the careful and exact exploration of special glacial districts not hitherto adequately investigated. They began with the valley of the River Calder, including its tributaries, from its source to its junction with the River Aire, near to Castleford. This valley has been subdivided into geographical areas, each of which is now placed under the supervision of a sub-committee. The results of this exploration they hope to embody in their next annual report. They intend also to present a similar report on the Sedbergh, Garsdale, and Dentdale district, now being investigated after the same fashion.

During the past year a sub-committee has been engaged upon the preparation of a new and enlarged glacial map of Yorkshire on a scale of

one inch to the mile. This map they hope to exhibit at the meeting of the British Association in 1893.

The following erratic blocks have been recorded during the year.

Reported by J. J. MARSHALL, Esq., *Chemist, Market Weighton.*

On Mr. Brough's Farm, Reformatory Road, Market Weighton:

An isolated Jurassic sandstone boulder, 19 × 13 × 10 in.; angular, with rounded edges. No rocks like it near, only gravels and sands of a similar character: recently found when ploughing, now removed to near the farmhouse.

Reported by JOHN STEARS, Esq., *Hull.*

On England Farm, near Winstead, Holderness—

A Mountain Limestone boulder, 4 ft. 3 in. × 2 ft. 3 in. × 1 ft. 7 in.; subangular; resting on a gravelly bed; under 50 ft. above sea level.

Some years ago a larger boulder of the same colour, weighing several tons, was found in the same field and broken up for road metal.

Reported by JOHN H. PHILLIPS, Esq., *Hon. Sec. Scarborough Philosophical and Archæological Society.*

Group.

In the gardens of King's Cliff Hospital, Scarborough, fifty-eight boulders of all shapes and sizes, from 4 ft. 8 in. and 26 in. in circumference up to 11 ft. 8 in. by 9 ft. 6 in. Striations nearly illegible. They include four basalts, two hard limestones, and fifty-two Shap granites from half a hundredweight up to two tons in weight. Collected by their former owner, John Wharton, Esq., from the coast and highways in the immediate neighbourhood.

The estate has recently been sold, and is to be converted into winter gardens; but it is hoped this fine group of erratics will be transferred to the Scarborough Museum.

Reported by W. GREGSON, Esq., *Baldersby, Thirsk.*

N. Yorkshire.—Northam Tower, Rokeby: altitude 450 feet—

Basalt 20 in. in diameter, rounded; resting on Carb. limestone.

Egglestone Abbey, Startforth: altitude 500 feet—

Shap granite, 24 × 15 × 15 in.; subangular; resting on Carb. limestone.

Startforth, near Barnard Castle, on right bank of Tees—

Shap granite,	50 × 36 × 30 in.;	subangular;	resting on	Carb. limestone.
„	48 × 30 × 27 in.	„	„	„
„	diameter 12 in.;	rounded	„	„
„	32 × 28 × 26 in.;	subangular	„	„
„	30 × 12 × 10 in.	„	„	„
Grey granite	36 × 18 × 12 in.	„	„	„

Pickhill, near Thirsk: altitude 100 feet—

Basalt, 18 × 15 × 14 in.; subangular; resting on drift overlying Keuper sandstone.

Sinderby, near Thirsk: altitude about 90 feet—

Carboniferous limestone, 30 × 20 × 18 in.; subangular; on Keuper sandstone; striæ, N.E. and S.W., in the direction of its long axis.

Reported by Thos. Tate, *F.G.S., Hon. Secretary to the Yorkshire Boulder Committee.*

Ribblesdale: altitude 350 feet.—Swanside Beck (right bank), east of Sawley Abbey—

I. 'Brockram,' somewhat bleached, 14 × 17 × 6 in.; rounded. May be from the Permian conglomerate of Black Burton (the Leck beds brockram), which is indistinguishable from that of the Vale of Eden.

II. Black limestone breccia, richly veined with calcite and limonite, 12 × 6 × 6 in.; very angular. Parent rock unknown.

Ingleton.—I. Dale Beck (right bank), above Phillips' dyke: altitude 470 feet—

Helmsgill lamprophyre, 72 × 39 × 19 in.; subangular.

II. Dale Beck (right bank), near Mealbank limekilns: altitude 400 feet—

Helmsgill lamprophyre, 72 × 60 × 42 in.; angular.

Microscopic sections of these boulders are described and figured in 'Proc. of Yorks. Geol. and Poly. Society,' vol. xi. p. 311, plates xiv., xv.

Dewsbury.—Gas works, Savile Town: altitude 125 feet—

I. Ennerdale granophyre, 7 × 4 × 4 in.; well worn.
II. Buttermere granophyre, 12 × 8 × 6 in.; rounded.

Church Street (near County Court, in main drainage): altitude 125 feet—

Shap (?) granite, 16 × 7 × 5 in.; oval; very much worn.

Horbury Bridge: altitude 100 feet—

Ennerdale granophyre, 7 × 5 × 5 in.; rounded.

Wakefield.—Thornes Lane, below suspension bridge: altitude 76 feet—

Ennerdale granophyre, 6 × 4 × 3 in.; well rounded.

All the above Calder Valley erratics, as well as those from Ribblesdale, are now in the possession of the Yorkshire Boulder Committee.

Teeside.—Shap granite, Armboth quartz, felsite, and Carrock Fell gabbro have been seen by the reporter in boring operations, ranging from 30 ft. to 120 ft. in depth, at North Ormesby and South Bank, as well as north of the Tees estuary.

Lancashire.

* *Second List of Erratics recorded by* Mr. S. S. Platt, *of Rochdale.*

The first was given in the Report of the Committee last year, in which the following errata have to be corrected.

No. 205 should be 217, and the locality should be '85 yards west of the Rochdale Town Hall.' It is now placed in the park near the Esplanade, and within a few yards of the place where it was originally found.

No. 181. The description should read 'red-brown grit, like that at Ending, N.W. of Rochdale.' Group Nos. 196–205, for 'Hardy' read 'Hartley.'

Continuation of Group 196–204, 19th report—

(205) 5 ft. 9 in. × 5 ft. 3 in. × 4 ft. 3 in.; approximate weight 10 tons; subangular; top somewhat irregular, but on being turned over the underside was found to be polished and flattened with rounded edges. It was imbedded in sand, which continued over a yard below it; but, on a careful examination of an irregularity on the underside of the boulder, clay was found imbedded therein, so that it appears to have been originally deposited in boulder clay, and that its present position is due to denuding agency. It has probably rolled from a neighbouring hill-top. (Immediately underneath it was a boulder of rhyolite about 6 in. × 4 in., rounded.) The direction of the longest axis as it lay was 115° E. of N. (W.N.W. by W. to E.S.E. by E.) height above O.D. about 550 ft. The upper surface of the boulder was level with the ground. A photograph was taken of it before disturbance, and afterwards of the underside, showing polished and flattened part; no distinct scratches were visible, having probably been obliterated by the weathering; andesite with epidote, weathered, at least $\frac{1}{2}$ in. deep.

In Mr. Thos. Holt's Brickyard at Castleton, near the Rochdale Canal, $1\frac{2}{3}$ mile S.S.E. of centre of Rochdale. Above O.D. about 475 feet.

(206) 1 ft. 3 in. × 10 in. × 7 in.; subangular; polished and rounded on top; porphyrite.
(206A) 10 in. × 9 in. × 7 in.; rounded; Buttermere granophyre.
(207) 10 in. × 9 in. × 8 in.; subangular; Buttermere granophyre.
(208) 3 ft. 6 in. × 3 ft. × 1–9 in.; subangular to rounded; weathered; flattened on top side and striated lengthways; ? Creetown granite, or Galloway district.
(209) 3 in. × 3 in. × 2 in.; subangular; Galloway granite.
(210) 8 in. × 5 in. × 3 in.; flattened one side and striated in every direction; Canky flagrock.
(211) 5 in. × 4 in. × 3 in.; pink sandstone.
(212) 1 ft. 3 in. × 9 in. × 7 in.; rounded; flat one side; porphyrite.
(213) 4 in. × $2\frac{1}{2}$ in. × 2 in.; rhyolite.

Back Lane, Castleton—

(214) 2 ft. × 1 ft. 4 in. × 1 ft.; subangular, with flattened sides; andesite.

Sparth Bottoms, Norman Road, Rochdale (continuation of group 105–127B, 19th Report)—

(218) 9 in. × 6 in. × 4 in.; subangular; flattened top and bottom; green and red porphyrite.
(219) About 6 in. diameter; rounded; red porphyrite.
(220) About 3 in. diameter; rounded; Galloway granite.
(222) 2 ft. × 1 ft. 8 in. × 1 ft.; rectangular, direction taken before removal from boulder clay in which it was situated 8 ft. from top of clay, and about 17 ft. below original surface; direction of largest axis, which also corresponded with striæ on top, N.N.E. to S.S.W. (20° W. of S.); ferruginous coloured flaggy sandstone containing plant remains.

Two more similar, but smaller, at same horizon, striated on top; direction N.W. to S.E. and N.N.W. to S.S.E.

At Cross Road, St. Anne's to Kirkham, crossing road between Lytham and Blackpool, near Hey's Houses, about 2 miles N. of Lytham.

(223) 1 ft. 9 in. × 1 ft. × 1 ft.; angular; striated and rounded on one side, apparently top; porphyrite.
(224) 2 ft. × 1 ft. 9 in. × 1 ft.; subangular to round; andesite.

(225) 2 ft. × 1 ft. 3 in. × 1 ft.; subangular; granite (? locality).
(226) 1 ft. 4 in. × 1 ft. 2 in. × 1 ft.; subangular with rounded corners; flattened one side, which is very much grooved and striated in direction parallel throughout to longest axis; another flat side not exactly in same plane, this is only smoothed; Galloway granite.
(227) 1 ft. 9 in. × 1 ft. 4 in. × 7 in.; flat one side; remainder rounded to subangular; andesite.
(228) 1 ft. 8 in. × 1 ft. 3 in. × 8 in.; subangular; flattened two sides, and striated one side diagonally across longest axis; granite (? locality).
(229) 1 ft. 8 in. × 1 ft. 4 in. × 1 ft.; subangular; near wheelwright's shop; Galloway granite (cf. Dalry).
(230) 1 ft. 6 in. × 1 ft. 2 in. × 1 ft.; subangular; no striation, but smoothed and rounded; Buttermere granophyre.

Heywood Road, Castleton, 450 ft. O.D.—

(231) 1 ft. 6 in. × 1 ft. 3 in. × 1 ft. 3 in.; subangular to round; felstone.
(277) 1 ft. 3 in. × 1 ft. × 7 in.; subangular; flattened and smoothed one side; Galloway granite (cf. Dalry).
(278) 1 ft. 3 in. × 1 ft. × 11 in.; angular; andesite.

Near 'Moor Cock Inn,' Swaindrod, Blackstone Edge Road. 690 ft. O.D. 4¼ miles N.E. by E. of centre of Rochdale.

(232) 1 ft. 7 in. × 1 ft. 4 in. × 1 ft. 4 in.; piece broken off; subangular to round Gneissic granite; ? S.W. of Scotland.

Hopwood Brickyard, near Heywood (continuation of group 58–81, 19th report)—

(233) 7 in. × 5½ in. × 3½ in.; subangular; black limestone with pecten (?) shell.
(234) 3 in. × 2 in.; subangular; granite (cf. Cairnsmore of Fleet).

Occupation Road from Yew Tree Farm to Hopwood Hall, 1½ mile S.S.E. of centre of Heywood. 450 ft. O.D.

(234A) 2 ft. 8 in. × 2 ft. 3 in. × 2 ft. (+); rounded on N. side of Occupation Road, opposite entrance to farmyard (Shepherd's); Buttermere granophyre.
(235) Subangular; rounded corners; flattened on top; weathered; andesite.
(236) 2 ft. × 1 ft. 3 in. (+) × 9 in.; oval-shaped; subangular; gateway to Kay's Farm; volc. breccia.
(237) 4 ft. 2 in. × 3 ft. 4 in. × 2 ft.; subangular; no marks of striation visible; on south side of road, 80 yards W. of Oaken Bank Wood; granite (? Criffel) with veins of quartz; rhyolite.
(238) 2 ft. × 2 ft. × 1 ft. 5 in. (+); rounded to subangular; weathered smooth N. side of road opposite Stackyard; andesite.
(239) 4 ft. 2 in. × 1 ft. 6 in. × 1 ft. 10 in.; flattened one side, which is striated lengthways; in plantation behind stables, Hopwood Hall; granite (? Galloway).
(240) 2 ft. × 1 ft. 6 in. × 1 ft. 3 in.; subangular; in road near stable, Hopwood Hall; granite.

In field 50 yards S. of Moorside Farm, 1⅓ mile due south of centre of Rochdale. About 525 ft. O.D.—

(242) 10 in. × 6½ in. × 5 in.; oval; much weathered; Halleflinta.
(243) 1 ft. 6 in. × 1 ft. 2 in. × 9 in.; oval; weathered; striated on one side in parallel lines in direction of breadth (1 ft. 2 in.); Eskdale granite.
(244) 1 ft. 3 in. × 1 ft. × 10 in.; irregular; no striations; Gannister, with Stigmarian root-marks.

In Cripplegate Lane, about 400 yards S. of last group—

(245) 2 ft. 3 in. × 1 ft. 8 in. × 10 in. (+); broken; irregular: Eskdale granite.
(246) About 10 in. diameter; volc. agglomerate.
(247) 10 in. × 8 in. × 6 in. (+); quartzite.

At Bradshaw Edge Farm, $\frac{1}{3}$ mile S. of Moorside=$1\frac{2}{3}$ mile S. of centre of Rochdale. About 575 ft. O.D.

(248) 1 ft. 3 in. × 8 in. × 9 in. (+); irregular; andesite.
(249) 6 in. × 4 in. × 4 in.; round; andesite with iron pyrites.
(250) 9 in. × 8 in. × 5 in.; oval; volc. breccia.
(251) 1 ft. 3 in. × 1 ft. 1 in. × 9 in. (+); oval; granite (?).
(252) 1 ft. 8 in. × 1 ft. 4 in. × 1 ft.; oval; andesitic agglomerate.
(254) 8 in. × 7 in. × 4 in.; oval; Buttermere granophyre.
(255) 1 ft. × 1 ft. 1 in. × 1 ft. 1 in.; rounded; Eskdale granite.

All these found in fields and lanes near to, by present tenant, who has lived here 30 years.

At Langden End Mill, $3\frac{2}{3}$ miles East by North of centre of Rochdale. About 720 ft. above O.D. Excavated out of boulder clay near brook—in forming settling tanks—and in brook adjoining—

(257) 1 ft. 6 in. × 1 ft. 6 in. × 1 ft.; subangular; weathered; ? Needle's Eye, syenite, or var. of Buttermere granophyre.
(260) 9 in. diameter; rounded; andesite.
(261) 8 in. diameter; rounded; Buttermere granophyre.
(262) 3 ft. 6 in. × 2 ft. 6 in. × 2 ft.; subangular; porphyritic andesite.
(263) 2 ft. 6 in. × 1 ft. 6 in. × 1 ft. 4 in.; subangular; porphyritic andesite.
(264) 1 ft. 8 in. × 1 ft. 6 in. × 1 ft.; subangular; Buttermere granophyre.
(265) 1 ft. 6 in. × 1 ft. 6 in. × 1 ft.; subangular; quartz felsite
(266) 1 ft. 3 in. × 1 ft. 1 in. × 1 ft. 4 in; rounded; Needle's Eye, ? Buttermere.
(267) 1 ft. 4 in. × 1 ft. 2 in. × 8 in.; flattened; Needle's Eye; ? Buttermere.
(268) 1 ft. 2 in. × $10\frac{1}{2}$ in. + 6 in.; oval; felsitic ash.
(269) 7 in. × 3 in. × 4 in.; Eskdale granite.
(270) 1 ft. 9 in. × 1 ft. 3 in. × 1 ft.; Needle's Eye (?).
(271) 2 ft. × 1 ft. × 1 ft.; andesite with large porphyritic crystals of epidote.
(272) 9 in. × 6 in. × 4 in.; granite, Galloway.
(273) Broken; Eskdale granite.
(302) 1 ft. 9 in. × 1 ft. 6 in. × 1 ft. 4 in.; subangular; irregular; andesite with hornblende.
(343) 1 ft. × 10 in. × 10 in.; angular to subangular; porphyrite; L.D.
(344) 1 ft. 8 in. × 1 ft. 8 in. × 1 ft. (+); subangular; Buttermere granophyre (variety)
(345) 2 ft. × 1 ft. 8 in. × 1 ft. 8 in.; subangular; quartz felsite with epidote.
(346) 2 ft. 6 in. × 1 ft. 8 in. × 1 ft. 8 in.; subangular; Buttermere granophyre.
(347) 8 in. × 10 in. × 8 in.; subangular; Eskdale.
(348) 3 ft. × 1 ft. 8 in. × 1 ft. 8 in.; subangular; andesite.
(349) 1 ft. × 9 in. × 8 in.; subangular; rhyolite.
(350) 1 ft. 6 in. × 1 ft. × 8 in.; subangular; andesite.
(351) 2 ft. × 1 ft. × 1 ft.; subangular; quartz felsite with epidote.
(352) 6 in. × 4 in. × 4 in.; subangular to round; ? Needle's Eye, or Buttermere variety.
(353) 2 ft. 2 in. × 1 ft. 10 in. × 1 ft. 10 in.; subangular; Buttermere granophyre.
(354) 1 ft. 5 in. × 1 ft. 2 in. × 1 ft.; subangular; same as 352.
(355) 1 ft. 6 in. × 1 ft. 3 in. × 1 ft. 1 in.; rectangular, with rounded edges; Buttermere granophyre variety.
(356) 1 ft. × 9 in. × 6 in.; subangular; Eskdale granite.
(357) 3 ft. × 2 ft. 6 in. × 1 ft. 3 in. (visible); angular to subangular; in brook about 20 yards east of bridge; granite (? Galloway district).
(303) 5 ft. × 4 ft. 6 in. × 2 ft. (visible); subangular; no marks visible; weathered; Buttermere granophyre; on Nicholas Pike, about $\frac{1}{4}$ mile S.E. of last group, 1,050 ft. O.D., position marked on Geol. Survey Map.

* *Report on the Boulders on the Shore of the River Mersey, from Dingle Point to Hale Head.* *By* JOSEPH LOMAS, *A.R.C.S.*, Special Lecturer on Geology, University College, Liverpool.

From Herculanean Dock to Dingle Point—

(1) 35 in. × 28 in. × 18 in.; pear-shaped; andesite.
(2) 31 in. × 21 in. × 15 in.; grit; silurian.
(3) 39 in. × 39 in. × 22 in.; rounded; polished; and grooved at top and sides; andesite.

In first creek beyond Dingle Point—

(4) 59 in. × 49 in. × 42 in.; rounded; andesite.
(5) 27 in. × 23 in. × 21 in.; rounded; andesite.
(6) 33 in. × 27 in. × 13 in.; tabular; Criffel granite.
(7) 31 in. × 28 in. × 20 in.; rounded; Criffel granite.
(8) 56 in. × 42 in. × 24 in.; pear-shaped; well planed and striated, Scotch granite.
(9) 23 in. × 17 in. × 14 in.; rounded; Dalbeattie granite.

Knott's Hole—

(10) 55 in. × 42 in. × 30 in; well rounded; andesite.
(11) 54 in. × 39 in. × 32 in.; well rounded; striated axially; felsite.
(12) 42 in. × 26 in. × 18 in.; rounded; striated at top; andesite.
(13) 23 in. × 18 in. × 8 in.; well rounded; andesite.
(14) 39 in. × 39 in. × 24 in.; polished on lower surface; diorite.
(15) 51 in. × 25 in. × 25 in.; well rounded; polished; and striated axially; andesitic agglomerate.

Between Knott's Hole and Southwood Road—

(16) 31 in. × 29 in. × 17 in.; polished; Scotch granite.
(17) 33 in. × 18 in. × 13 in.; subangular; Scotch granite.
(18) 31 in. × 24 in. × 12 in.; polished and striated axially, and also at right angles; grit.
(19) 54 in. × 28 in. × 14 in.; tabular; Dalbeattie.
(20) 40 in. × 31 in. × 20 in.; well rounded; beautifully polished; grit.
(21) 18 in. × 15 in. × 10 in.; polished and striated; andesite.
(22) 25 in. × 22 in. × 16 in.; well rounded; polished; andesitic ash.
(23) 16 in. × 12 in. × 18 in.; rounded; striated axially; silurian grit.
(24) 37 in. × 27 in. × 20 in.; well rounded; polished; ash.
(25) 50 in. × 40 in. × 16 in.; planed and grooved axially; grit; tabular.
(26) 46 in. × 22 in. × 22 in.; rounded and pear-shaped; blunt end fractured and not at all worn; polished on other faces; Dalbeattie granite.

From Southwood Road to Otterspool—

(27) 21 in. × 20 in. × 13 in.; polished and striated axially; andesite.
(28) 16 in. × 12 in. × 12 in.; nodular; diorite.
(29) 24 in. × 13 in. × 12 in.; striated axially; striæ on upper and lower surfaces; andesitic ash.
(30) 23 in. × 12 in. × 17 in.; andesite.
(31) 21 in. × 14 in. × 12 in.; andesite.
(32) 23 in. × 15 in. × 12 in.; well rounded; striated axially; andesite.
(33) 24 in. × 16 in. × 13 in.; tabular; white sandstone.
(34) 31 in. × 20 in. × 12 in.; well rounded; striated obliquely to axis; andesite
(35) 17 in. × 13 in. × 13 in.; limestone.
(36) 24 in. × 16 in. × 13 in.; andesite.
(37) 17 in. × 13 in. × 13 in.; subangular; silurian grit.
(38) 18 in. × 17 in. × 16 in.; rounded; Yewdale breccia.
(39) 18 in. × 13 in. × ?; andesite.
(40) 22 in. × 16 in. × 9 in. (+); tabular; Dalbeattie granite.
(41) 20 in. × 12 in. × 12 in.; rounded; polished; andesite.
(42) 27in. × 12 in. × 12 in. (+); rounded and polished; granite.

(43) 30 in. × 16 in. × ?; ash.
(44) 24 in. × 15 in. × 10 in. (+); rounded; andesite.
(45) 29 in. × 21 in. × 12 in. (+); tabular; smooth; Dalbeattie granite.
(46) 29 in. × 18 in. × 10 in. (+); tabular; smooth; Criffel granite.
(47) 24 in. × 11 in. × 11 in. (+); andesite.
(48) 25 in. × 21 in. × ?; tabular; smooth; Yewdale breccia.
(49) 26 in. × 18 in. × 12 in. (+); andesite.
(50) 33 in. × 20 in. × 20 in. (+); rounded; Criffel granite.
(51) 56 in. × 36 in. × 22 in. (+); tabular; Yewdale breccia.
(52) 31 in. × 31 in. + 20 in. (+); well polished; Dalbeattie granite.
(53) 29 in. × 14 in. × 16 in.; subangular; silurian grit.
(54) 19 in. × 17 in. × 11 in.; well rounded; polished; andesitic agglomerate.
(55) 22 in. × 13 in. × 6 in.; angular; diorite.
(56) 16 in. × 14 in. × 9 in.; striated axially; andesite.
(57) 23 in. × 14 in. × 10 in.; rounded; andesitic agglomerate.
(58) 23 in. × 18 in. × 11 in.; rounded; polished; Dalbeattie granite.
(59) 22 in. × 23 in. × 16 in.; rounded; andesite.
(60) 20 in. × 16 in. × 11 in.; andesite.
(61) 27 in. × 17 in. × 13 in.; Criffel granite.
(62) 32 in. × 22 in. × 10 in.; pear-shaped; striated axially; andesite.
(63) 45 in. × 32 in. × ?; pear-shaped; subangular; andesite.
(64) 59 in. × 36 in. × 36 in.; striated axially; diorite.
(65) 96 in. × 50 in. × 16 in. (+); polished and grooved axially; axis N. and S.; andesite.

Embankment near Mersey Road—

(66) 45 in. × 39 in. × 24 in.; limestone with silurian corals.
(67) 36 in. × 27 in. × 12 in.; tabular; Eskdale granite.
(68) 26 in. × 20 in. × 11 in.; pear-shaped; striated obliquely; silurian grit.
(69) 35 in. × 25 in. × 19 in.; well scratched; basalt.
(70) 34 in. × 36 in. × 31 in.; diorite.
(71) 26 in. × 21 in. × 9 in. (+); andesite.
(72) 27 in. × 21 in. × 12 in. (+); Dalbeattie granite.
(73) 27 in. × 24 in. × 12 in. (+); Yewdale breccia.
(74) 27 in. × 24 in. × 9 in. (+); diabase.
(75) 28 in. × 22 in. × 9 in. (+); andesite

From Embankment to Riversdale Road—

(76) 31 in. × 24 in. × 16 in.; polished and deep wide grooves; Yewdale breccia.
(77) 27 in. × 24 in. × 14 in.; pear-shaped; granite, Criffel.
(78) 41 in. × 33 in. × 22 in.; pear-shaped; Dalbeattie.
(79) 22 in. × 21 in. × 18 in.; polished beautifully, but no striæ; ash.
(80) 40 in. × 31 in. × 11 in. (+); Criffel.
(81) 41 in. × 32 in. × 16 in.; tabular; rounded; Scotch granite.
(82) 44 in. × 34 in. × 19 in.; tabular; striated axially; granite, fine-grained
(83) 32 in. × 21 in. × 23 in.; well rounded; smooth; granite.
(84) 26 in. × 20 in. × 16 in.; subangular; granite, Scotch.
(85) 27 in. × 16 in. × 12 in.; diabase (?).

Corner of Foundy Garston—

(86) 40 in. × 32 in. × 18 in.; well rounded; granite.

Shore at Garston, near Battery—

(87) 38 in. × 37 in. × 17 in.; polished top; axially striated; striæ N. and S. from N.; axis, N. and S.; andesite.
(88) 29 in. × 22 in. × 14 in.; pear-shaped, point S.; polished; axis, N. and S.; granite.
(89) 24 in. × 15 in. × 9 in.; rounded; polished; andesite.
(90) 24 in. × 13 in. × 14 in.; fractured; Dalbeattie.
(91) 19 in. × 17 in. × 9 in.; rounded; Dalbeattie.
(92) 47 in. × 42 in. × 16 in.; grooves N. and S.; axis, N. and S.; *in situ*; Criffel.
(93) 48 in. × 34 in. × 22 in.; striated axially; polished; axis, N. and S.; andesite.
(94) 38 in. × 24 in. × 16 in.; polished one side; fractured; Dalbeattie.

Group.

Near targets—

(95) 26 in. × 24 in. × 12 in; axis, N. and S.; granite, Scotch.
(96) 39 in. × 37 in. × 25 in.; striæ from N.; axis, N. and S.; granite, Scotch.
(97) 29 in. × 17 in. × 17 in.; axis, N. and S.; andesite.

Close to target—

(98) 30 in. × 28 in. × 9 in.; polished and grooved from N.; axis, N. and S. striated pavement; Dalbeattie.
(99) 23 in. × 20 in. × 12 in.; striæ; axis, N. and S.; striated pavement; andesite.
(100) 28 in. × 26 in. × 14 in.; scratched N. and S.; axis, E. and W.; striated pavement; limestone.
(101) 28 in. × 17 in. × 17 in.; scratched N. and S.; axis, N. and S.; striated pavement; granite.
(102) 34 in. × 28 in. × 12 in.; tabular; scratched E. and W.; striated pavement.

Beyond target—

(103) 45 in. × 37 in. × 20 in.; diabase.

Oglet Point—

(104) 27 in. × 12 in. × 14 in.; N. end thinner; axial and normal; axis, N. and S.; silurian grit.
(105) 23 in. × 20 in. × 15 in.; rounded; Criffel granite.
(106) 23 in. × 21 in. × 12 in.; diorite.
(107) 17 in. × 14 in. × 8 in.; Criffel granite.
(108) 22 in. × 9 in. × 10 in.; pear-shaped, blunt to N.; axial; polished; andesitic agglomerate.
(109) 20 in. × 16 in. × 10 in.; Dalbeattie.
(110) 30 in. × 17 in. × 24 in.; Scotch granite.
(111) 43 in. × 32 in. × 21 in.; striated; andesite.

Crow's Nest to Hale Head—

(112) 21 in. × 18 in. × 12 in.; axial; axis, N. and S.; Dalbeattie granite.
(113) 35 in. × 28 in. × 18 in.; pear-shaped blunt S.; polished beautifully; axial; axis, N. and S.; andesite.
(114) 34 in. × 24 in. × 18 in.; rounded; axial; axis, N. and S.; andesite.
(115) 29 in. × 21 in. × 20 in.; polished; axial; axis, N. and S.; andesite.
(116) 25 in. × 19 in. × 12 in.; subangular; axial; axis, N. and S.; andesite.
(117) 28 in. × 20 in. × 18 in.; rounded; axial; axis, N. and S.; Scotch granite.
(118) 23 in. × 22 in. × 18 in.; polished; axis, N. and S.; Scotch granite.
(119) 26 in. × 21 in. × 12 in.; round; polished; axis, N.E. and S.W.; Scotch granite.
(120) 29 in. × 18 in. × 18 in.; axial; axis, N.W. and S.E.; andesite.
(121) 25 in. × 21 in. × 6 in.; rounded angles; triangular; axial; axis, N. and S.; Scotch granite.
(122) 28 in. × 25 in. × 12 in.; axis, E. and W.; Scotch granite.
(123) 28 in. × 18 in. × 18 in.; triangular; polished; axis, E. and W.; Scotch granite.
(124) 22 in. × 18 in. × 18 in.; striæ transverse; axis, N. and S.; Scotch granite.
(125) 34 in. × 25 in. × 20 in.; axial; axis, N. and S.; andesite.
(126) 64 in. × 46 in. × 36 in.; rounded; polished; Scotch granite.
(127) 40 in. × 36 in. × 40 in.; polished; axis, N.E. and S.W.; Scotch granite.
(128) 24 in. × 22 in. × 20 in.; transverse; axis, SS.W. and N.N.E.; andesite.
(129) 22 in. × 22 in. × 12 in.; hexagonal; polished striæ; axis, N. and S.; andesite.
(130) 32 in. × 26 in. × 20 in.; axial; axis, N.W. and S.E.; andesite.
(131) Diam. 34 in.; circular; polished; granite.
(132) 38 in. × 31 in. × 24 in.; axis, E. and W.; granite.
(133) 30 in. × 22 in. × 24 in.; axis, N.W. and S.E.; granite.
(134) 32 in. × 24 in. × 16 in.; axial; axis, N.W. and S.E.; andesite.
(135) 28 in. × 20 in. × 20 in.; axial; axis, N.W. and S.E.; andesite.

Opposite Hale Lighthouse—

(136) 84 in. × 30 in. × 42 in.; andesite.

Mr. Arthur R. Dwerryhouse catalogues the following boulders in order, beginning at the Hale Head and working round to the Decoy Marsh.

Owing to the large number of boulders in so short a distance (about two miles), and the scarcity of fixed object by which to indicate their whereabouts, it has been impossible to give the exact position of each, so that they are merely catalogued in order, showing in the number column the position of any objects which may act as landmarks.

The great bulk of the boulders are evidently not *in situ*, having rolled down from the clay cliffs, and are at present lying in the river sand.

At a point about midway between the Head and the Rifle Butts there is little sand, and a number of boulders are seen *in situ* embedded in the surface of the clay, and these, together with a number of smaller ones (also *in situ*) not enumerated in the report, show great regularity as regards the direction of their axes and striæ.

It will further be noticed that, as one moves round the shore, the striæ become further and further from the north and south line.

This conforms to the observed direction of the striæ on the rocks at Farnworth Church and Runcorn Gap, points still further up the river, at the last of which the direction is E. and W.

* *Report on the Boulders on the Shore between Hale Head and the Decoy Marsh, Hale, Lancashire.* *By* ARTHUR R. DWERRYHOUSE.

(1) 24 in. × 18 in. × ?; rounded; axis, 35° W. of N.; partly buried in clay, *in situ*; granite, Dalbeattie.
(2) 18 in. × 12 in. × 12 in.; rounded; slightly striated; andesitic breccia with iron pyrites.
(3) 14 in. × 12 in. × 6 in.; subangular; planed; andesite.
(4) 15 in. × 12 in × 7 in.; subangular; planed and striated; andesite.
(5) 24 in. × 22 in. × 15 in.; subangular; planed and striated; andesite, Borrowdale.
(6) 42 in. × 39 in. × 24 in.; subangular; axis, 35° W. of N.; planed; granite Dalbeattie.
(7) 24 in. × 17 in. × 15 in.; subangular; weathered on surface; andesite.
(8) 18 in. × 13 in. × 4 in.; rounded; planed; andesite.
(9) 24 in. × 18 in. × 14 in.; subangular; striated axially; granophyre, Buttermere.
(10) 22 in × 15 in. × 9 in.; subangular; planed; granite, Criffel.
(11) 18 in. × 12 in. × 6 in.; subangular; striated axially; diorite.
(12) 24 in. × 21 in. × 11 in; subangular; planed and striated; andesite.
(13) 24 in. × 21 in. × 17 in.; subangular; slightly planed; andesite.
(14) 16 in. × 10 in. × 5 in.; subangular; striated axially; silurian grit.

Hedge—

(15) 18 in. × 16 in. × 6 in.; pear shape; striated axially; andesite.
(16) 22 in. × 13 in. × 10 in.; angular; granite, much mica and some iron pyrites.
(17) 25 in. × 20 in. × 13 in.; subangular; much broken, and having a spoon-shaped hollow on one side; striated axially; silurian grit.
(18) 19 in. × 16 in. × 7 in.; subangular; planed; felsite (?) contains small pink felspars.
(19) 31 in. × 26 in. × 24 in.; rounded; planed; andesite.
(20) 32 in. × 26 in. × 22 in.; rounded; planed; andesitic agglomerate.

(21) 24 in. × 16 in. × 10 in.; subangular; much weathered; silurian grit.
(22) 14 in. × 12 in. × 9 in.; subangular; planed; andesite.
(23) 36 in. × 24 in. × 24 in.; subangular; striated axially; granite, Eskdale.
(24) 28 in. × 24 in. × 18 in.; subangular; striated axially; granite, Eskdale.
(25) 24 in. × 13 in. × 17 in.; angular; fractured; granophyre, Buttermere.
(26) 21 in. × 19 in. × 10 in.; rounded; planed and striated; andesite.
(27) 21 in. × 10 in. × 12 in.; rounded; partly buried in sand; granophyre, Buttermere.
(28) 25 in. × 20 in. × 13 in.; subangular; granophyre, Buttermere.
(29) 16 in. × 15 in. × 14 in.; rounded; planed; felsite (?)
(30) 22 in. × 17 in. × 11 in.; rounded; planed; andesite.
(31) 28 in. × 23 in. × 20 in.; subangular; planed; granite, Dalbeattie.
(32) 24 in. × 22 in. × 22 in.; subangular; planed and striated; granite, Dalbeattie.
(33) 22 in. × 18 in. × 14 in.; subangular; slightly striated; granophyre, Buttermere.
(34) 14 in. × 8 in. × 7 in.; subangular; slightly striated; triassic sandstone.
(35) 24 in. × 24 in. × 12 in.; subangular; striated; granite, Dalbeattie.
(36) 42 in. × 30 in. × 21 in.; subangular; axis, 30° E. of N.; not *in situ*; andesite.
(37) 26 in. × 20 in. × 12 in.; subangular; axis, 40° W. of N.; *in situ*; granite, Dalbeattie.
(38) 30 in. × 22 in. × 15 in.; angular; andesitic agglomerate.
(39) 12 in. × 9 in. × 6 in.; subangular; axis, 35° W. of N.; striated axially, *in situ*; andesite.
(40) 14 in. × 10 in. × 8 in.; subangular; axis, 35° W. of N.; *in situ*; granite, Eskdale.
(41) 14 in. × 9 in. × 5 in.; rounded; axis, 35° W. of N.; striated axially, *in situ*; granite, Scotch (? Dalry).
(42) 18 in. × 18 in. × 16 in.; rounded; axis, 35° W. of N.; striated axially, *in situ*; andesite.
(43) 15 in. × 15 in. × 15 in.; angular; not planed; diorite.
(44) 24 in. × 18 in. × 12 in.; subangular; axis, 35° W. of N.; striated axially; granite, Dalbeattie.
(45) 30 in. × 21 in. × 3 in. (+); rounded; buried in river mud; granite, Criffel.
(46) 27 in. × 22 in. × 14 in.; subangular; axis, 30° W. of N.; striated axially; granite, Eskdale.
(47) 15 in. × 12 in. × ?; subangular; axis, 35° W. of N.; striated axially, *in situ*; andesite.
(48) 21 in. × 20 in. × 12 in.; subangular; not striated; granite, Dalbeattie.
(49) 24 in. × 18 in. × 12 in.; subangular; not striated; granite, Dalbeattie.
(50) 12 in. × 12 in. × 6 in.; subangular; axis, S. 35° W. of N.; striated; andesite.
(51) 36 in. × 30 in. × 15 in.; subangular; axis, 35° W. of N.; striated axially; granite, Scotch fine grain.
(52) 30 in. × 27 in. × 18 in.; subangular; planed; andesite.
(53) 27 in. × 24 in. × 21 in.; subangular; axis, 35° W. of N.; striated axially; andesite.
(54) 30 in. × 21 in. × 12 in.; rounded; slightly striated; granite, Dalbeattie.
(55) 18 in. × 10 in. × 10 in.; subangular; axis, 35° W. of N.; planed; granite, Criffel.

Group.

(56) 24 in. × 18 in. × 15 in.; rounded; axis, S. 35° W. of N.; striated, *in situ*; andesite.
(57) 18 in. × 15 in. × 12 in.; rounded; axis, S. 35° W. of N.; striated axially, *in situ*; andesite.
(58) 30 in. × 18 in. × 12 in.; subangular; striated axially; andesite.
(59) 30 in. × 18 in. × 12 in.; subangular; axis, 40° W. of N.; planed, *in situ*; andesite.
(60) 15 in. × 15 in. × 10 in.; rounded; axis, 40° W. of N.; planed, *in situ*; andesite.
(61) 24 in. × 20 in. × 12 in.; rounded; weathered; granite, Criffel.
(62) 18 in. × 18 in. × 12 in.; rounded; striated; andesite.

(63) 21 in. × 21 in. × 12 in.; subangular; axis, S. 40° W. of N.; striated, *in situ*; granite, Scotch fine grain.
(64) 18 in. × 15 in. × 9 in.; subangular; axis, 40° W. of N.; striated axially; andesite.
(65) 30 in. × 18 in. × 15 in.; subangular; axis, 35° W. of N.; striated axially; andesite agglomerate.
(66) 33 in. × 33 in. × 15 in.; subangular; striated; andesite.
(67) 18 in. × 10 in. × 6 in.; rounded; planed; andesite.
(68) 27 in. × 12 in. × 12 in.; subangular; axis, 35° W. of N.; striated axially; andesite.
(69) 16 in. × 12 in. × 8 in.; rounded; axis, 30° W. of N.; striated axially; granite, Dalbeattie.
(70) 27 in. × 21 in. × 10 in.; subangular; striated axially; andesite.
(71) 30 in. × 24 in. × 24 in.; subangular; granite, Dalbeattie.
(72) 34 in. × 27 in. × 14 in.; angular; andesite.

Group.

Hedge—

(73) 41 in. × 21 in. × 18 in.; rounded; striated axially; andesite.
(74) 16 in. × 15 in. × ?; rounded; buried in sand; granite, Criffel.
(75) 19 in. × 15 in. × 5 in. (+); subangular; buried in sand; andesite.
(76) 19 in. × 19 in. × 7 in. (+); angular; buried in sand; andesite.
(77) 15 in. × 15 in. × 7 in. (+); rounded; buried in sand; andesite.
(78) 36 in. × 19 in. × 7 in. (+); rounded; buried in sand; granite, Criffel.
(79) 24 in. × 15 in. × 15 in.; subangular; planed; granite, Criffel.
(80) 17 in. × 11 in. × 15 in.; subangular; planed; andesitic agglomerate.
(81) 17 in. × 14 in. × 11 in.; subangular; planed; andesite.
(82) 24 in. × 24 in. × 6 in. (+); subangular; resting on clay; granite; Criffel.
(83) 18 in. × 12 in. × 6 in. (+); subangular; striated; granophyre, Buttermere.
(84) 15 in. × 12 in. × 6 in.; angular; andesite.
(85) 24 in. × 22 in. × 15 in.; subangular; planed; andesite.

Group.

(86) 24 in. × 21 in. × 20 in.; subangular; axis, 60° W. of N.; planed; andesite.
(87) 23 in. × 18 in. × 10 in.; subangular; axis, S. 60° W. of N.; striated axially; andesite.
(88) 30 in. × 30 in. × 18 in.; subangular; axis, S. 60° W. of N.; striated; andesite.
(89) 24 in. × 16 in. × 12 in.; subangular; axis, 60° W. of N.; planed; granite, Dalbeattie.

Group.

(90) 30 in. × 22 in. × 15 in.; subangular; granite, Scotch (? Dalry).
(91) 26 in. × 14 in. × 12 in.; angular; fractured; andesite.
(92) 31 in. × 20 in. × 18 in.; subangular; planed; andesite.
(93) 24 in. × 24 in. × 14 in.; rounded; axis, S. 50° W. of N.; striated; granite, Eskdale.
(94) 17 in. × 16 in. × 8 in.; rounded; striated; andesite.
(95) 24 in. × 23 in. × 12 in.; rounded; planed; andesite.
(96) 28 in. × 22 in. × 15 in.; subangular; andesite.
(97) 22 in. × 16 in. × 12 in.; subangular; silurian grit.
(98) 18 in. × 14 in. × 8 in.; subangular; axis, S. 40° W. of N.; striated axially; andesitic agglomerate.
(99) 24 in. × 19 in. × 9 in.; rounded; planed; andesite.
(100) 18 in. × 15 in. × 12 in.; rounded; planed; andesitic agglomerate.

Group.

(101) 18 in. × 13 in. × 10 in.; subangular; fractured; andesite.
(102) 39 in. × 33 in. × 30 in.; subangular; andesite.
(103) 24 in. × 15 in. × 12 in.; rounded; andesitic agglomerate.

(104) 17 in. × 15 in. × 10 in.; rounded; striated; andesite.
(105) 15 in. × 8 in. × 6 in.; subangular; striated axially; granite, Dalbeattie.
(106) 14 in. × 14 in. × 9 in.; rounded; granite, Buttermere.
(107) 30 in. × 24 in. × 12 in.; subangular; striated axially; granite, Scotch fine grain.
(108) 25 in. × 14 in. × 8 in.; subangular; granite, Scotch (? Dalry).
(109) 25 in. × 19 in. × 12 in.; subangular; axis, 45° W. of N.; striated axially *in situ*; granite.
(110) 20 in. × 13 in. × 12 in.; angular; andesitic agglomerate.
(111) 18 in. × 12 in. × 9 in.; angular; andesite.
(112) 24 in. × 24 in. × 18 in.; rounded; striated in several directions, buried in mud; andesite.
(113) 19 in. × 18 in. × 12 in.; subangular; almost buried in mud; andesite.
(114) 32 in. × 27 in. × 15 in.; rounded; almost buried in mud; granite, Eskdale
(115) 30 in. × 17 in. × 10 in.; subangular; planed; andesite.
(116) 24 in. × 22 in. × 12 in.; subangular; planed; granite, Eskdale.
(117) 30 in. × 18 in. × 18 in.; subangular; planed; andesite.
(118) 32 in. × 18 in. × 12 in.; subangular; granite, Eskdale.
(119) 34 in. × 19 in. × 12 in.; subangular; granite, Eskdale.
(120) 17 in. × 13 in. × 12 in.; subangular; andesite.
(121) 33 in. × 22 in. × 6 in. (+); pear shape; weathered; granite, Scotch.
(122) 30 in. × 24 in. × 12 in. (+); subangular; planed and striated; andesitic agglomerate.
(123) 30 in. × 22 in. × 18 in.; pear shape; planed; andesitic agglomerate.
(124) 32 in. × 24 in. × 12 in. (+); subangular; planed and striated; andesite.
(125) 21 in. × 14 in. × 10 in.; subangular; granite, Scotch.
(126) 38 in. × 22 in. × 12 in. (+); subangular; planed and weathered; granite, Scotch.
(127) 28 in. × 20 in. × 15 in.; subangular; slightly planed; granite, Eskdale.
(128) 40 in. × 30 in. × 18 in. (+); subangular; planed and striated; andesitic agglomerate.
(129) 27 in. × 24 in. × 9 in. (+); rounded; planed and striated; andesite.
(130) 40 in. × 22 in. × 30 in.; angular; slightly planed on one surface; granite, Scotch.
(131) 32 in. × 25 in. × 14 in.; subangular; planed and striated; ? diorite.
(132) 24 in. × 18 in. × 16 in.; rounded; fractured; granite, Eskdale.
(133) 31 in. × 22 in. × 18 in.; subangular; not striated; andesite.
(134) 20 in. × 18 in. × 18 in.; rounded; planed; andesitic agglomerate.
(135) 30 in. × 18 in. × 12 in. (+); subangular; planed slightly; granite, Eskdale.
(136) 24 in. × 15 in. × 8 in.; angular; fractured; andesitic agglomerate.
(137) 20 in. × 15 in. × 11 in.; rounded; planed and striated; andesitic agglomerate.
(138) 26 in. × 16 in. × 12 in. (+); angular; slightly planed on one surface; granite, Criffel.
(139) 36 in. × 24 in. × 12 in.; subangular; axis, 45° W. of N.; *in situ*, planed; granite, Eskdale.
(140) 19 in. × 15 in. × 16 in.; pear shape; planed; granite, Eskdale.
(141) 19 in. × 13 in. × 12 in.; subangular; planed and striated; andesitic agglomerate.
(142) 24 in. × 24 in. × 12 in. (+); rounded; planed and striated; andesite.
(143) 27 in. × 18 in. × 12 in.; subangular; fractured; granite, Eskdale.
(144) 17 in. × 12 in. × 6 in.; subangular; planed and striated; silurian grit.
(145) 22 in. × 16 in. × 9 in.; subangular; planed and striated; andesitic agglomerate.
(146) 25 in. × 14 in. × 14 in.; angular; slightly planed; andesitic agglomerate.
(147) 34 in. × 36 in. × 18 in.; subangular; planed; andesite.
(148) 22 in. × 14 in. × 10 in.; angular; slightly planed and striated; andesitic agglomerate.
(149) 32 in. × 18 in. × 12 in.; rounded; planed; andesite.
(150) 25 in. × 18 in. × 12 in.; pear shape; planed; granite, Eskdale.
(151) 21 in. × 14 in. × 10 in.; rounded; planed and striated; sandstone.
(152) 23 in. × 20 in. × 18 in. (+); subangular; planed; granite, Eskdale.
(153) 23 in. × 20 in. × 9 in.; subangular; planed; granite, Scotch.
(154) 24 in. × 22 in. × 10 in.; subangular; much planed and striated; andesite.

(155) 20 in. × 12 in. × 6 in.; subangular; planed; sandstone.
(156) 19 in. × 12 in. × 12 in.; angular; slightly planed; granite, Scotch.
(157) 20 in. × 19 in. × 10 in.; subangular; planed and striated; andesitic agglomerate.
(158) 18 in. × 13 in. × 10 in. (+); rounded; planed: granite, Scotch.
(159) 30 in. × 20 in. × 12 in. (+); angular; planed and slightly striated; ? diabase.
(160) 25 in. × 22 in. × 12 in.; angular; slightly planed; andesite.
(161) 20 in. × 20 in. × 6 in. (+); subangular; planed and slightly striated; granite, Scotch.
(162) 24 in. × 14 in. × 12 in. (+); subangular; planed and striated; andesitic agglomerate.
(163) 19 in. × 18 in. × 6 in. (+); subangular; planed and striated; granite, Eskdale.
(164) 26 in. × 24 in. × 18 in.; rounded; planed; granite, Scotch.
(165) 46 in. × 42 in. × 24 in.; subangular; planed; granite, Scotch.
(166) 14 in. × 10 in. × 10 in.; subangular; planed and striated; andesite.
(167) 22 in. × 20 in. × 12 in.; subangular; planed and striated; andesitic agglomerate.

Hedge—

(168) 19 in. × 17 in. × 6 in. (+); subangular; planed; granite, Eskdale.
(169) 29 in. × 20 in. × 8 in. (+); subangular; planed; granite, Dalbeattie.
(170) 24 in. × 16 in. × 6 in. (+); subangular; planed and striated; andesite.
(171) 32 in. × 28 in. × 18 in. (+); angular; planed slightly; granite, Dalbeattie.
(172) 42 in. × 36 in. × 28 in. (+); subangular; planed; granite, Dalbeattie.
(173) 18 in. × 18 in. × 15 in.; angular; andesite.
(174) 50 in. × 30 in. × 30 in.; angular; slightly planed; andesite.
(175) 28 in. × 26 in. × 18 in.; subangular; planed and striated; granite, Eskdale.
(176) 24 in. × 13 in. × 8 in.; angular; diorite.
(177) 18 in. × 17 in. × 4 in. (+); subangular; planed; granite, Dalbeattie.
(178) 24 in. × 19 in. × 7 in. (+); subangular; andesite.
(179) 27 in. × 16 in. × 18 in.; subangular; planed and striated; andesite.
(180) 22 in. × 19 in. × 20 in.; subangular; planed and fractured; granite, Dalbeattie.
(181) 30 in. × 26 in. × 22 in.; subangular; andesite.

Rifle Butts—

(182) 20 in. × 11 in. × 14 in.; angular; silurian grit.
(183) 24 in. × 20 in. × 8 in. (+); subangular; granite, Dalbeattie.
(184) 30 in. × 18 in. × 15 in.; subangular; planed and striated; andesite.
(185) 26 in. × 24 in. × 9 in.; subangular; planed and striated; silurian grit.
(186) 24 in. × 15 in. × 11 in.; angular; planed and striated; andesite.

Witten Lane—

(187) 18 in. × 12 in. (+) × 12 in.; rounded; planed; granite, Dalbeattie.
(188) 15 in. × 12 in. × 8 in.; angular; planed and slightly striated; andesite.
(189) 30 in. × 24 in. × 6 in. (+); subangular; axis, 55° W. of N.; planed and striated, *in situ*; andesite.
(190) 24 in. × 15 in. × 15 in.; subangular; planed and striated; silurian grit.
(191) 20 in. × 15 in. × ?; subangular; andesite.
(192) 15 in. × 8 in. × 8 in.; angular; andesite.
(193) 24 in. × 24 in. × ?; subangular; planed; andesite.
(194) 41 in. × 23 in. × 24 in. (+); angular; granite, Criffel.
(195) 18 in. × 12 in. × 12 in.; angular; slightly planed; granite, Dalbeattie.
(196) 40 in. × 26 in. × 12 in. (+); angular; andesite.
(197) 30 in. × 22 in. × 16 in.; subangular; planed; granite, Dalbeattie.
(198) 24 in. × 22 in. × ?; rounded; planed; granite, Dalbeattie.
(199) 23 in. × 18 in. (+) × 12 in. (+); subangular; planed; andesite.
(200) 12 in. × 12 in. × 12 in.; rounded; planed; granite, Criffel.
(201) 15 in. × 12 in. × 6 in.; angular; andesite.

Fence of Salt Marsh—

(202) 19 in. × 12 in. × 12 in.; angular; planed and striated; andesite.

Cheshire.

* *Reported by* Joseph Lomas, *A.R.C.S.*

Mid Wirral.—Probably very few of the following boulders are *in situ*. They are mostly situated at cross roads and in farmyards.

Opposite Grange Farm, Little Storeton—

(1) 18 in. × 12 in. × 12 in.; pear-shaped; diorite.

Group at Little Storeton—

(2) 12 in. × 12 in. × 6 in.; planed and striated; Yewdale breccia
(3) 21 in. × 18 in. × 18 in.; rounded; Scotch granite.
(4) 18 in. × 12 in. × 9 in.; silurian grit.
(5) 15 in. × 12 in. × ?; diorite.

Opposite school—

(6) 18 in. × 15 in. × 8 in; Yewdale breccia.
(7) 24 in. × 14 in. × 12 in.; striated; andesite (?)
(8) 16 in. × 16 in. × 9 in.; striated; andesite.

Storeton, near farm gate—

(9) 22 in. × 20 in. × 18 in.; rounded and striated; andesite.
(10) 16 in. × 9 in. × 12 in.; andesite.
(11) 21 in. × 15 in. × 12 in.; andesite.
(12) 24 in. × 18 in. × 9 in.; silurian grit.
(13) 24 in. × 15 in. × 21 in. (+); diorite.
(14) 26 in. × 18 in. × 15 in.; Scotch granite.
(15) 16 in. × 15 in. × 10 in.; andesite.

Brimstage—

(16) 15 in. × 6 in. × 12 in.; rounded; Scotch granite.
(17) 18 in. × 13 in. × 14 in.; striated; andesite.
(18) 16 in. × 12 in. × 9 in.; Scotch granite.
(19) 28 in. × 24 in. × 14 in.; andesite.
(20) 25 in. × 14 in. × 15 in.; andesite.

Near Red Cat Inn, Brimstage—

(21) 20 in. × 14 in. × 12 in.; andesite.
(22) 14 in. × 12 in. × 12 in.; andesitic agglomerate.
(23) 18 in. × 15 in. × 12 in.; andesite.
(24) 16 in. × 12 in. × 15 in.; limestone.
(25) 17 in. × 18 in. × 8 in. (+); planed; silurian grit.
(26) 16 in. × 14 in. × 12 in.; andesite.

In Pinfold, Brimstage—

(27) 22 in. × 22 in. × 15 in.; silurian grit.
(28) 27 in. × 18 in. × 16 in.; andesite.
(29) 27 in. × 24 in. × 20 in.; striated and planed; andesit
(30) 15 in. × 13 in. × 12 in.; andesite.
(31) 12 in. × 14 in. × 16 in.; andesite.

Near Pinfold—

(32) 18 in. × 15 in. × 16 in.; andesite.
(33) 24 in. × 12 in. × 18 in.; andesite.
(34) 18 in. × 14 in. × ?; grit.
(35) 15 in. × 10 in. × 9 in.; andesite.
(36) 21 in. × 18 in. × 14 in.; andesite.
(37) 14 in. × 12 in. × 12 in.; andesite.

Near cross roads—

(38) 39 in. × 28 in. × 18 in.; planed and striated; andesite.
(39) 22 in. × 18 in. × 20 in.; andesite.

On road to Spital—

(40) 15 in. × 14 in. × 10 in.; planed and striated; andesite.

Sandy Lane Pit—

(41) 18 in. × 14 in. × 15 in.; andesite.
(42) 16 in. × 15 in. × 10 in.; andesite.

Storeton Road—

(43) 20 in. × 15 in. × 15 in.; andesite.

Roadside near Spital Station—

(44) 17 in. × 10 in. × 8 in.; rounded and striated; felsite.
(45) 16 in. × 10 in. × 9 in.; rounded; silurian grit.
(46) 22 in. × 14 in. × 8 in.; striated and rounded; andesite.

Opposite Spital Old Hall—

(47) 15 in. × 12 in. × 8 in.; rounded; andesite.
(48) 16 in. × 9 in. × 6 in.; striated and planed; striæ axial; silurian grit.

Group in Spital Old Hall Yard—

(49) 22 in. × 24 in. × 22 in.; striated; Scotch granite.
(50) 13 in. × 14 in. × 7 in.; planed and striated axially; Buttermere granophyre.
(51) 19 in. × 14 in. × 9 in.; planed and striated axially; andesite.
(52) 17 in. × 12 in. × 8 in.; planed and striated axially; andesite.
(53) 15 in. × 8 in. × 10 in.; rounded; felsite.
(54) 14 in. × 9 in. × 8 in.; rounded; Buttermere granophyre.
(55) 24 in. × 17 in. × 9 in.; rounded and striated axially; felsite.
(56) 18 in. × 16 in. × ?; planed and striated; felsite.
(57) 17 in. × 14 in. × ?; planed and striated; andesite.
(58) 16 in. × 11 in. × ?; planed and striated; silurian grit.
(59) 14 in. × 10 in. × ?; felsite.
(60) 17 in. × 13 in. × 8 in. (+); silurian grit.
(61) 18 in. × 14 in. × ?; planed; andesite.
(62) 22 in. × 12 in. × ?; striated; felsite.
(63) 17 in. × 11 in. × ?; andesite.
(64) 17 in. × 17 in. × 9 in.; planed and striated; andesite.
(65) 26 in. × 19 in. × 12 in. (+); andesitic ash.
(66) 14 in. × 15 in. × 18 in. (+); rounded and striated; andesite.
(67) 16 in. × 10 in. × 6 in.; planed and striated; silurian grit.

In the yard there are hundreds of lesser size which range up to 12 inches diameter. There are a large number of felsites and several white sandstones which greatly resemble gannister.

Group at roadside, opposite Hall—

(68) 22 in. × 17 in. × 14 in.; rounded; Scotch granite.
(69) 24 in. × 16 in. × 11 in.; andesite.
(70) 18 in. × 13 in. × 8 in.; andesite.
(71) 19 in. × 16 in. × 8 in.; andesite.
(72) 17 in. × 12 in. × 12 in.; Scotch granite.
(73) 21 in. × 14 in. × 10 in.; gannister; ? white sandstone.
(74) 18 in. × 18 in. × 8 in.; ash.
(75) 19 in. × 10 in. × 19 in.; striated axially; silurian grit.
(76) 19 in. × 15 in. × 12 in.; rounded; andesite.
(77) 23 in. × 15 in. × 12 in.; rounded; andesite.
(78) 18 in. × 16 in. × 11 in.; rounded; andesite.
(79) 21 in. × 18 in. × 14 in.; rounded; andesite.
(80) 19 in. × 15 in. × 10 in.; rounded; felsite.

On Neston Road, opposite Pinfold—

(81) 31 in. × 24 in. × ?; Scotch granite.

Road to Clatterbridge—

(82) 14 in. × 13 in. × 12 in.; Scotch granite.
(83) 24 in. × 21 in. × 12 in. (+); planed; andesite.

Near Clatterbridge—

(84) 15 in. × 12 in. × 12 in.; rounded; andesite.
(85) 15 in. × 16 in. × 10 in.; andesite.
(86) 20 in. × 18 in. × 12 in.; striated and rounded; andesite.
(87) 19 in. × 15 in. × 10 in.; silurian grit.
(88) 17 in. × 14 in. × 8 in.; striated and planed; felsite.

Road to Thornton Hough—

(89) 18 in. × 13 in. × 10 in.; rounded; striated and planed; granite.
(90) 21 in. × 20 in. × 12 in.; rounded; andesite.
(91) 18 in. × 18 in. × 10 in.; planed and striated; ? gannister.
(92) 20 in. × 18 in. × 12 in.; rounded; Criffel granite.
(93) 22 in. × 18 in. × 12 in.; andesite.
(94) 25 in. × 12 in. × 8 in.; striated and planed; silurian grit.
(95) 20 in. × 13 in. × 10 in.; rounded; Dalbeattie granite.

Bye-road near Thornton Hough—

(96) 56 in. × 40 in. × 22 in.; rounded; striated axially; axis, 70° W. of N; andesitic agglomerate.

Near Thornton Hall—

(97) 20 in. × 13 in. × 16 in.; andesite.
(98) 40 in. × 16 in. × 24 in. (+); rounded; andesite.
(99) 18 in. × 14 in. × 19 in. (+); granite.
(100) 24 in. × 12 in. × 18 in.; granite.
(101) 30 in. × 14 in. × 20 in. (+); andesitic agglomerate.

Near farm, Thornton—

(102) 21 in. × 16 in. × 12 in.; andesite.
(103) 17 in. × 19 in. × 9 in.; andesite.
(104) 40 in. × 35 in. × 22 in.; striated and planed; andesite.
(105) 28 in. × 16 in. × 12 in. (+); andesite.
(106) 20 in. × 10 in. × ?; andesite.
(107) 36 in. × 30 in. × 14 in; andesite.
(108) 43 in. × 30 in. × 27 in.; granite.

Seven Stars Inn—

(109) 27 in. × 14 in. × 24 in. (+); granite.

Opposite Seven Stars Inn—

(110) 24 in. × 19 in. × 12 in.; granite.
(111) 20 in. × 16 in. × 12 in. (+); diabase.

Opposite Wesleyan Chapel—

(112) 33 in. × 20 in. × 18 in.; striated and planed; granite.
(113) 8 in. × 22 in. × 14 in.; andesite.

Opposite smithy—

(114) 38 in. × 26 in. × 12 in. (+); andesite.
(115) 22 in. × 17 in. × 10 in.; andesitic agglomerate
(116) 24 in. × 16 in. × 14 in.; silurian grit.

Bye-road near Little Grange—

(117) 24 in. × 20 in. × 12 in.; silurian grit.
(118) 20 in. × 18 in. × 12 in.; granite.

Boulders on Hilbre Island.

Near Little Eye, 80 yards N.W. of—

(1) 56 in. × 42 in. × 18 in.; well rounded; andesitic agglomerate.

200 yards N.W. of Little Eye—

(2) 90 in. × 84 in. × 42 in.; triangular in shape; well rounded; andesitic agglomerate.

300 yards from Little Eye—

(3) 30 in. × 18 in. × 12 in.; ? ash.
(4) 45 in. × 39 in. × 20 in.; diabase.

* *Reported by* Mr. J. A. Audley, *A.R.C.S.*

Boulders near Goyt Hall, Stockport.

(1) 42 in. × 24 in. × 27 in.; rectangular, subangular; Rigg o' Burnfoot granite.
(2) 90 in. × 84 in. × 42 in. (+); subangular; andesite.

* *Reported by* Mr. Wm. Mawby, *of Birkenhead.*

Particulars of a group of 25 boulders lying on West Kirby Beach, a few yards from the base of the Boulder Clay Cliffs, south of the Hydropathic.

(1) 20 in. × 18 in. × 10 in.; pentagonal; subangular; no striæ; basalt.
(2) 18 in. × 16 in. × 12 in.; square; subangular; striated; granite.
(3) 30 in. × 20 in. × 20 in.; rounded; disintegrated; no striæ; basalt.
(4) 16 in. × 12 in. × 12 in.; rounded; disintegrated; no striæ; basalt.
(5) 33 in. × 24 in. × 16 in.; oblong; subangular; no striæ; andesite.
(6) 32 in. × 26 in. × 18 in.; oblong; subangular; no striæ; granite.
(7) 37 in. × 27 in. × ?; square; subangular; planed, no striæ; andesite.
(8) 24 in. × 21 in. × 12 in.; pear shaped; subangular; planed, no striæ; limestone.
(9) 24 in. × 18 in. × 12 in.; polygonal; subangular; no striæ; granite.
(10) 27 in. × 18 in. × 12 in.; pear shaped; subangular; no striæ; granite.
(11) 28 in. × 15 in. × 10 in.; oblong; subangular; no striæ; andesite.
(12) 30 in. × 24 in. × 12 in.; oblong; subangular; no striæ; andesite.
(13) 28 in. × 21 in. × 14 in.; rounded; subangular; no striæ; basalt.
(14) 18 in. × 18 in. × 14 in.; rounded; subangular; no striæ; andesite.
(15) 28 in. × 20 in. × 10 in.; pear shaped; subangular; striated; andesitic agglomerate.
(16) 30 in. × 20 in. × 16 in.; oblong; subangular; no striæ; andesite.
(17) 26 in. × 21 in. × 15 in.; polygonal; subangular; no striæ; granite.
(18) 26 in. × 24 in. × 15 in.; triangular; subangular; no striæ; granite.
(19) 20 in. × 18 in. × 8 in.; triangular; subangular; planed and striated andesite.
(20) 22 in. × 18 in. × 12 in.; rounded; subangular; planed; andesitic agglomerate.
(21) 26 in. × 12 in. × 10 in.; oblong; subangular; no striæ; andesite.
(22) 22 in. × 16 in. × 12 in.; oblong; subangular; no striæ; andesite.
(23) 22 in. × 18 in. × 6 in.; pentagon; subangular; no striæ; granite.
(24) 17 in. × 16 in. × 6 in.; square; subangular; no striæ; granite.
(25) 24 in. × 15 in. × 8 in.; oblong; subangular; no striæ; andesite.

The longest axis is in almost every case 10° West of North.

* *Reported by* Mr. Thomas Kay, *J.P., of Stockport.*

Marple.—Wood Farm, in the field next the farmhouse, on the N.E.—A block of Lake District Andesite, about 1 ft. 8 in. long.

* *Reported by* Mr. J. W. Gray, *F.G.S., of Stockport.*

Woodley.—In clay-pit behind Buckley's Mill, amongst a large assemblage of Lake District and Scottish rocks, two blocks of Ardwick Limestone (Upper Coal-measures), exactly resembling that which occurs *in situ* at Levenshulme. There is no known outcrop nearer to Woodley.

Derbyshire.

* *Reported by* Mr. Joseph Lomas, *A.R.C.S.*

Boulders occurring in the neighbourhood of Hayfield, Derbyshire.

Near Railway Inn, Hayfield—

18 in. × 14 in. × 10 in.; subangular; andesite.
30 in. × 24 in. × 14 in.; rounded and polished; andesite.
40 in. × 30 in. × 20 in.; well polished; andesitic agglomerate.

Near railway station—

32 in. × 28 in. × 20 in.; well rounded; moved to present site, found in the brook; andesite.

30 in. × 26 in. × 12 in.; andesite.

Opposite Bull's Head—

24 in. × 14 in. × 12 in.; rounded; Buttermere.

At Royal Hotel gate—

24 in. × 24 in. × 18 in.; rounded; andesite.
26 in. × 20 in. × 16 in.; rounded; andesite.

In brook, opposite Farlands—

24 in. × 24 in. × 12 in.; Buttermere.

Cross roads, Little Hayfield—

30 in. × 30 in. × 12 in.; planed and striated axially; Buttermere
27 in. × 20 in. × 14 in.; rounded; Buttermere.

In the Clough—

24 in. × 20 in. × 12 in.; Buttermere.

Opposite Board School, Hayfield—

27 in. × 24 in. × 12 in.; rounded; Buttermere.

Road to Kinder, near Royal Hotel—

36 in. × 24 in. × 30 in.; Eskdale granite.

Opposite Walk Mill Chapel—

Two boulders, both andesites, almost circular, one 18 in. and the other about 15 in. diameter.

In the neighbourhood there are many rounded pieces of millstone grit, some of which must be boulders, but the quarries in the neighbourhood contain many rounded concretions, and the rounded appearance of some blocks found isolated by the roadside may be due to this cause.

North Wales.

* *Reported by* Mr. A. C. Nicholson, *F.G.S., of Oswestry.*

Llanymynech Hill, 6 miles S. of Oswestry, and in the parishes of Oswestry, Llanyblodwel, and Llanymynech.

In 'Bottom-rock' quarry, 650 ft. above O.D.—

2 ft. × 1 ft. 6 in. × 1 ft.; rounded; argillite.

Associated with this were many blocks of Caradoc sandstone, trap, and local limestone. They occurred in a bed of gravel graduating downward into a red stony clay, which rested upon a surface of limestone striated from 22° S. of W. to 22° N. of E. In a disused quarry known as Charles Roberts's Pant, in the township of Crickheath, 590 ft. above O.D., another surface showed striæ from 12° S. of W. to 12° N. of E.

* *Reported by* Rev. C. R. Barker, *B.A., S.J., of St. Beuno's College, St. Asaph.*

Tremeirchion, near St. Beuno's College. A small piece of the Eurite of Ailsa Craig.

Worcestershire.

* *Reported by* Mr. George Gray, *of Worcester.*

Worcester.—From a gravel pit about 30 ft. above the present level of the River Severn the following series was obtained, representing all the varieties that could be found—

Vein quartz, 1.
Agate, 1.
Buttermere granophyre, 1.
Welsh lavas, 3.
Welsh agglomerate, 1.
Flint, 1.
Eskdale granite (the typical aspect as well as varieties), 9
Scottish granites (these are all of familiar Galloway types, and include rocks much resembling the varieties found at Creetown and Rigg o' Burnfoot), 6.
Rhyolite of the Wrekin, 1.
U. Llandovery limestone (a block about 9 in. long, containing Stricklandinia), 1.

Isle of Man.

* *Reported by* Rev. S. N. Harrison, *of Ramsey.*

Maughold.—On the high road between Port-e-Vullyn and the Cairn. Small boulders of granite, under 1 ft. in diameter, lie scattered on both sides of the hill, especially towards the eastern portion of the north side on Balladromma. On the top of the range at East Ballatesson, on Magher-lough—

(1) 2 ft. × 1 ft. 6 in. × 1 ft.; Biotite granite.
(2) 1 ft. 6 in. × 1 ft. × 1 ft.; Biotite granite.
(3) 1 ft. 4 in. × 1 ft. × 1 ft.; Biotite granite.

and other smaller ones.

On the Cronk—

(1) Fragments of a boulder calculated to have been 4 ft. long; andesitic agglomerate; rounded; striated longitudinally.
(2) 3 ft. long; grit; now broken into fragments.
(3) 2 ft. × 1 ft. 4 in. × 8 in.; grit.
(4) 1 ft. × 10 in. × 8 in.; granite, oval.

On the Glebe—

Small boulders of vein-quartz and grit.

On the Cairn.—Small boulders under 6 inches in diameter of Loch Doone granite and Buttermere granophyre.

Above the Village of Maughold.—Many blocks of vein-quartz and clay slate (local), with an occasional trap boulder.

From Maughold down to Port Mooar are a number of small granites and red sandstone. In a line from the Rheast, across by Ballakelly farmhouse to Crow Villa, are several grey granites and grits in or near the fences, and smaller groups may be seen at the well on Ballakelly; near the farmhouse of Ballater East; and at Crow Villa.

On the Hills from Claghbane, S.E., to Ballaskaig.—

On Claghbane, 350 ft. above O.D.—

(1) 1 ft. × 10 in. × 8 in.; granite of Dalbeattie.
(2) 10 in. × 8 in. × 6 in.; granite of Loch Skerrow (?).
(3) 3 ft. × 2 ft. 6 in. × 2 ft.; grit.

Several granites under 2 ft. in diameter lie scattered about the fields nearer to Ramsey, besides blocks under 1 ft. in diameter of red sandstone and greenstone.

On Balla Stole.—One red sandstone under 6 in. in diameter and blocks of grit and vein-quartz.

In Ballure Glen.—A large number of boulders of grit both angular and rounded. Above the bridge are two granites—

(1) 4 ft. × 2 ft. × 1 ft. 10 in.
(2) 1 ft. 6 in. × 1 ft. 4 in. × 1 ft.

Below the bridge are two granites under 1 foot in diameter, one slaty conglomerate 3 ft. × 2 ft. × 2 ft., and a diabase 2 ft. in diameter.

E. of Ballure on top of Diabase Quarry—

(1) 6 in. × 4 in. × 2 in.; greenstone; well scratched.

Blocks of this rock (the diabase) have been carried in a S. and S.E. direction to Slieu Lewaigue. No foreign rocks have been noticed, but only blocks of grit, clay slate, and vein-quartz.

On Balla Creggan.—Grit and vein-quartz.

On Ballasaig, 430 ft. above O.D.—

(1) 3 ft. in diameter; granite; angular; now split.
(2) 3 ft. in diameter; granite; rounded; now split.

This is the highest point at which a large boulder of granite has been found.

(3) 6 in. in diameter; red based; porphyry.

There are small pebbles of quartz and silurian grit to be found between here and Ballafayle.

On Ballafayle.—There are blocks of grit and vein-quartz 4 ft. in diameter.

On the S. side of these hills, down to the stream Stroan-a-Vreck, which runs from near the foot of North Barrule to Corna Bridge, I have noticed only three granite boulders. They are in a line with the Corna School, as if they had come across the river there, not far from the place where the other larger boulders are on Ballasaig. One of these—1 ft. 6 in. × 1 ft. 6 in. × 10 in. is near the farmhouse at Magher-a-breck; another, at Ballaglass, is 2 ft. × 2 ft. × 10 in.; and the third, to the Westward of the Corna School, on Booley Vett, is 10 in. × 8 in. × 6 in. The other boulders on these lands are grit and vein-quartz, chiefly angular.

On the S. side of North Barrule.—Below the Shepherd's cottage are a group of grits, varying in size from 6 ft. downward, lying in a mass of rubble. These are local. Above Cardle Voar are also several similar blocks trending down in an easterly direction. The largest are—

(1) 5 ft. × 4 ft. × 3 ft.
(2) 4 ft. × 3 ft. 6 in. × 2 ft. 6 in.

all angular.

In the old road S.E. from Cardle, on the south side of Ballaglass, are other blocks from the same grit—

(1) 6 ft. × 4 ft. × 3 ft.; oval.
(2) 3 ft. × 2 ft. 6 in. × — ; triangular.
(3) 10 ft. × 5 ft. × 2 ft. 6 in.; angular.
(4) 9 ft. × 5 ft. × 6 ft. 4 in.; in stream.

Above Magher-e-Kew are others of micaceous grit—

(1) 6 ft. × 3 ft. 6 in. × 3 ft.; angular.
(2) 4 ft. × 2 ft. × 10 in.
(3) 5 ft. × 2 ft. 4 in. × 3 ft.; oval.

Down Ballaglass, in an easterly direction, on Thalloo Loash, is a group of some 300 blocks of the micaceous grit, varying in size up to 6 ft. × 4 ft. × 3 ft., and one granite 2 ft. × 2 ft. × 10 in.

Between the stream of Stroan-a-Vreck and Corna Stream, in the plantation of Ballaglass above Corna Mill, are some hundreds of blocks of grit and vein-quartz. Many of these have been collected at the junction of the stream. Below the bridge, down the side of Rhenab, are also a large number of angular blocks of grit varying in character, some micaceous, while others bear a resemblance to granite.

These blocks appear to have travelled in an easterly direction, and somewhat downhill to their present positions.

Below here a patch of boulder-clay is exposed. On the lands of Rhenab and Corrany are scattered blocks of grit-quartz, vein-quartz, and clay slate. Some of these have been carried in a south-easterly direction. One of the largest—10 ft. × 6 ft. × 5 ft., an oval boulder of grit, lies in Rhenab Glen.

One in the Corrany, 3 ft. × 2 ft. 6 in. × 8 in., has an impression resembling a Lycopod on the flat side.

On the hills above these lands, from Corna river to Lonan, are vein-quartz and clay slate, many undisturbed.

In the granite district of the Dhoon blocks have been carried in a southerly–south-westerly direction, across Lonan to Onchan, and have been traced from Agneish by Lonan Church to Baldrine and down Groudale Valley.

[NOTE.—The pitchstone boulder at Port-e-Vullyn, recorded as No. 5 on

page 23 of the Nineteenth Report, has been identified by Professor Zirkel and others as the Pitchstone of Arran.

It is of especial interest, as boulders of the Eurite of Ailsa Craig occur in various parts of the Isle of Man.[1]]

Errata.

In the Report for 1873, p. 191:—

1. Dele *line* 1, *Charnwood Forest and other.*
2. „ „ 30, *Rocks of Charnwood Forest, from a distance of* 50 *miles.* The rocks supposed to have been derived from Charnwood Forest can be distinctly identified as having travelled from the Lake District.
3. The subjoined remark on the intermixture of boulders needs qualification to the extent of this correction.

Third Report of the Committee, consisting of Dr. HENRY WOODWARD (*Chairman*), Rev. G. F. WHIDBORNE, Messrs. R. KIDSTON, J. E. MARR, *and* A. S. WOODWARD (*Secretary*), *to consider the best methods for the Registration of the Type Specimens of British Fossils.* (*Drawn up by* A. S. WOODWARD.)

THE Committee have to report gradual progress in the registration of the type specimens of British fossils, but regret that it is still impossible to begin the tabulation of the results. Several important lists have been received during the year, and the printed catalogues of the collections at Cambridge (Woodwardian Museum), Bath, and Brighton, referred to in the last report, have now been issued. The lists, already at the disposal of the Committee, are enumerated below, and a special effort will shortly be made to obtain the remainder. The Keeper of the Department of Geology in the British Museum is making arrangements for the cataloguing of the types in the national collection, and when this task is completed the Committee will be the better able to consider the most satisfactory method of dealing with the whole of the material.

LISTS OF TYPE FOSSILS RECEIVED 1891–92.

Museums.—Bath, Belfast, Brighton, Bolton (Chadwick Museum), Bristol, Cambridge (Woodwardian Museum), Chester, Dorchester, Glasgow (Hunterian Museum), Halifax, Keswick, Leeds, Leicester, Ludlow, Manchester, Saffron Walden, Scarborough, Torquay, York.

Private Collections.—Messrs. R. Craig (Beith), J. W. Davis (Halifax), J. W. Kirkby (Leven), G. H. Morton (Liverpool), J. Postlethwaite (Keswick), D. Robertson (Millport), A. C. Savin (Cromer), R. H. Traquair (Edinburgh), E. A. Walford (Banbury), J. Ward (Longton), J. Windoes (Chipping Norton), and John Young (Glasgow). Also a list of the Grossart Collection (Salsburgh), prepared by Mr. John Young.

[1] *Proc. Lit. and Phil. Soc. of Manchester*, February 1891.

Third Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Dr. TEMPEST ANDERSON, Dr. VALENTINE BALL, Mr. JAMES E. BEDFORD, Professor T. G. BONNEY, Professor W. BOYD DAWKINS, Mr. JAMES W. DAVIS, Mr. EDMUND J. GARWOOD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. ARTHUR S. REID, Mr. R. H. TIDDEMAN, Mr. W. W. WATTS, Mr. HORACE B. WOODWARD, *and* Mr. OSMUND W. JEFFS (*Secretary*), *to arrange for the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom.* (*Drawn up by the Secretary.*)

IN presenting their third report your Committee desire to observe that although the number of photographs collected during the past year shows a decrease as compared with the two previous years, yet a greater proportion are of high scientific interest, and illustrate features of real geological importance. At first it was unavoidable that a considerable number of those received were only 'geological' photographs in a general sense. As explained in the last report,[1] it was not desired to restrict this term too greatly; but without some limit the collection would cease to represent typical geological features of the United Kingdom, and become simply a collection of landscape photographs.

The number of photographs received and registered from the date of the last report (August, 1891) to the end of June, 1892, is 112, bringing the total contents of the collection to 700. Owing to the early meeting of the Association this year, the list was closed before a complete twelve months' work could be recorded, and results have not yet reached the Committee from several of the societies which have undertaken local surveys for geological purposes. The following summary shows the geographical areas represented in the collection :—

ENGLAND:		Montgomeryshire	3
Berkshire	3	Northumberland	17
Cheshire	30	Shropshire	21
Cornwall	18	Somerset	12
Cumberland	2	Staffordshire	3
Derbyshire	21	Wiltshire	5
Devonshire	21	Worcestershire	2
Dorsetshire	18	Yorkshire	172
Durham	16	NORTH AND SOUTH WALES	72
Hampshire	2	SCOTLAND	52
Hertfordshire	4	IRELAND	123
Isle of Man	22	MICROSCOPIC SECTIONS	12
Kent	17		
Lancashire	30	Total	700
Leicestershire	2		

It will be seen from the foregoing that only about half of the English counties are represented in the collection, while the small amount of the contributions from several of those named in the list shows that considerable work is yet required to be done towards the completion of the scheme the Committee have in view.

[1] *Report* 1891, p. 321.

An exhibition of geological photographs was arranged in Section C at the Cardiff meeting.

Your Committee met at Cardiff and discussed details of the work. It was decided, on the recommendation of Dr. Tempest Anderson, to adopt a standard mount of uniform size for preserving the photographs. The style of mount adopted (known as the Zaehnsdorf 'self-binding' mount) is $15\frac{1}{2} \times 12$ inches, and is fitted with a special guard perforated at regular intervals for binding. This is of sufficient size to hold one whole-plate, or two half-plate, or four quarter-plate views. The views when mounted may be readily arranged in any desired order, and additions or substitutions effected. A supply of mounts has been obtained, and the collection is now in process of mounting and arrangement. Forms containing descriptive details of the photographs are affixed to the mounts. It has been arranged to supply these standard mounts to donors of photographs who are willing to mount their own views; otherwise the cost of mounting will fall on the Committee. It is found necessary to have the photographs properly mounted, not only for greater convenience of reference, but also to preserve them from possible injury by handling. The value of the collection is already considerable and will increase as it grows in numbers.

A new circular (No. 4) was issued by the Committee in November, and addressed to a large number of geologists and photographers (both professional and amateur), and also to scientific and photographic societies in all parts of the kingdom. While the Committee much appreciate the help that has been afforded from so many quarters, they would urge upon geologists generally the desirability of promptly assisting the scheme in order that their work may be proceeded with as quickly as possible. The Committee are indebted to the editors of 'Nature,' the 'Literary World,' 'English Mechanic,' 'Photographic News,' 'Amateur Photographer,' 'Globe,' 'Illustrated London News,' and other periodicals for giving prominence to their scheme for collecting and registering geological photographs.

The use of photographic processes for illustrating works on geology is becoming more frequent. During excursions of the Geologists' Association, several photographs have been taken by members from which 'tint-blocks' have been made to illustrate papers in the 'Proceedings' of the Association. In several counties active efforts are being made by local bodies for photographic surveys, and it is hoped that important geological phenomena may be made a feature of these surveys, and that copies of such photographs will be added to the collection formed by your Committee.

Reference was made in the last report to the appointment of a Committee on photographs by the Geological Society of America. The plan of this Committee is laid practically on the same basis as that of the British Association, the objects being (1) to make a photo-geological survey of America; (2) to exhibit the collection at the annual meetings of the Society; and (3) to publish a register of photographs received. The first register for 1890 contains a list of 293 photographs.

Your Committee deem it satisfactory that steps are thus being taken to carry out their own object in other countries.

Mr. C. J. Alford, F.G.S., mining engineer (of Suffolk House, Lawrence Pountney Hill, London), offered a series of geological photographs of subjects abroad, which the Committee were unable to accept owing to

their operations being confined to the British islands. At the desire of Professor W. Boyd-Dawkins, F.R.S., the information is now given, as it may be of interest to many members of the Association.

It has been suggested that, in order to save trouble in printing for the purpose of supplying copies to applicants, donors of photographs should make arrangements with local photographers, to whom their negatives may be entrusted, to execute orders for prints or lantern slides. This information is added in one case in the present report, and will be continued in future lists whenever a similar arrangement has been effected.

Your Committee have kept in view the question of the disposal of the photographs and the proposed publication of a selection of approved subjects, but recommendations on both these points are still deferred until it is seen to what extent the collection is likely to reach. They respectfully request reappointment with the object of further proceeding with the work, in order that the collection may not be too partial or incomplete, but may represent as nearly as possible all important geological formations exhibited in the British Islands. Their special efforts, during next year, will, it is proposed, be directed to obtaining photographs from the numerous localities not already included in the published lists. In this attempt, valuable assistance may be rendered by officers of the Geological Survey and local geologists by sending to the Secretary of the Committee early intimation of the opening of new sections showing features worthy of record by photography, in addition to particulars of old sections of typical importance, and localities of geological interest which have hitherto escaped record, or of which sketches and diagrams only have been published. It is hoped, too, that delegates of the Corresponding Societies and the officers of local Field Clubs or other bodies will bring the scheme before their members, and thus materially aid in making known the objects of the Committee.

Certain instructions have been drawn up, in order to secure uniformity of action, copies of which will be supplied on application to any member of the Committee. It is understood, however, that these are to be considered merely as a guide, and that all suitable photographs illustrating natural features of geological interest will be accepted for registration even if not complying with the whole of the recommendations stated in the circular, a copy of which is appended :—

Instructions for the Collection of Geological Photographs.

Photographs are desired illustrative of characteristic rock exposures, especially those of a typical character or temporary nature; important boulders; localities affected by denudation, or where marked physiographical changes are in operation; raised beaches; old sea-cliffs and other conspicuous instances of marine erosion; characteristic river-valleys or escarpments, and the like; glacial phenomena, such as *roches moutonnées*, moraines, drums and kames, or any natural views of geological interest. Photographs of microscopical sections and typical hand-specimens of rocks are also admissible.

I. The views should be taken under skilled geological direction, and the most typical views should be secured in preference to general views. Societies are urged to form committees for the purpose of noting sections suitable to be photographed, and arranging such work as may be possible in each district. To this end it is anticipated that the services of many amateur photographers may be usefully brought into requisition.

II. Size of photograph *recommended*: 8½ by 6½ inches ('whole plate'); but this is *optional*. In view of the difficulty of carrying a heavy camera and plates, it is not

desired to exclude smaller views when these are well-defined and clear. In the case of small negatives, when sharp, an enlargement to whole-plate size is desirable for the purpose of a place in the collection. The views should be printed by a permanent process whenever practicable. Isochromatic plates are strongly recommended to be used.

III. In order to preserve its scientific value, each photograph should be accompanied by as many of the following details as can be conveniently given. Forms for this purpose will be supplied on application.

(*a*) Name and position of section or locality.
(*b*) Special features shown, with illustrative diagrams, when necessary. (Further details may be given, if more convenient, on a separate tracing attached to the photograph.)
(*c*) Height and length of section, and compass direction.
(*d*) Name and address of photographer, or of the society under whose direction the view is taken.
(*e*) Date when photographed.
(*f*) Indication (where necessary) of direction of light and shade; *i.e.*, state whether taken in 'direct light' or 'in shade.'

IV. Each photograph sent in for registration should bear a *local* number, and the accompanying form should be numbered in accordance therewith.

V. Photographs should be sent *unmounted*. Mounts of uniform size, with perforated edges for binding, to hold one whole-plate, two half-plate, or four quarter-plate views, have been prepared, and a number will be forwarded, on application, to donors of photographs who prefer to mount their own prints.

VI. Lists of photographs, copies of photographic prints and information relative thereto should be sent under cover to the Secretary to the Committee, *at the earliest possible date*, in order to facilitate the work of registration.

THIRD LIST OF GEOLOGICAL PHOTOGRAPHS.

(TO JUNE, 1892.)

NOTE.—This list contains the subjects of geological photographs, copies of which have been received by the Secretary of the Committee since the publication of the last report. Photographers are asked to affix the registered numbers, as given below, to their negatives, for convenience of future reference.

Copies of any photographs desired can, in most instances, be obtained either from the photographer direct or from the officers of the local society under whose auspices the views were taken.

The Committee in no case have assumed the copyright of photographs registered, which is presumed to be held by the photographer.

The price at which copies of photographs may be obtained depends upon the size of the print and local circumstances, over which the Committee have no control.

ENGLAND AND WALES.

CHESHIRE.

Photographed by PRIESTLEY & SONS, *Egremont*. *Size* 8 × 6 *inches*.

Regd. No.		
631	The 'Red Noses,' New Brighton	Cliffs of Bunter sandstone
632	Wave study at Egremont.	Breakers in action

Denbighshire.

Photographed by Professor J. Campbell Brown, *D.Sc., University College, Liverpool. Size* 6×4 *inches.*

Regd. No.		
598–600	Eglwyseg Rocks, Llangollen	Escarpment of Carboniferous limestone

Photographed by Alfred O. Walker, *J.P., F.L.S., Nant-y-Glyn, Colwyn. Size* 6×4 *inches.*

601–602	Penmaenrhos . . .	Boulder clay, resting on Carboniferous limestone

Dorset.

Photographed by Captain Marshall Hall, *J.P., F.G.S., Easterton Lodge, Parkstone, R.S.O.*

589	Luscombe Hill, looking southwards ('Stromboli'?)	Flat-topped hills and table-land valley of denudation

Photographed by Miss M. K. Andrews, 12 *College Gardens, Belfast. Size* 6×4 *inches.*

680	Isle of Portland (47) . .	(47) Innosthay Quarry; fossil trees of Upper Dirt bed protruding through the 'Soft burr'
681–682	„ „ (48/9) .	(48/9) Innosthay Quarry; fossil trees of Upper Dirt bed protruding through the 'Soft burr' (nearer view)
683	„ „ (50) . .	Blocks of fossil wood
684	„ „ (51) . .	Fossil cycad

Durham.

Photographed by E. J. Garwood, *F.G.S.*, 14 *St. Mary's Place, Newcastle-on-Tyne. Enlargements marked* E. (*The negatives are placed with* Messrs. Andy & Ruddock, *Tynemouth.*)

621	Stanhope in Weardale Parson Byer's quarry	'Main' limestone [E]
622	Caldron Snout, Teesdale .	Erosion of Whin Sill [E]
623	Tyne Head, south of . .	Dyke crossing stream [E]
624	High Force, Middleton-in-Teesdale	Whin Sill resting on shales [E]
625	Burtree Ford . . .	Yoredale beds [E]
626	Fell between East Gate and West Gate, Stanhope in Weardale	Lead vein, weathered into a ridge [E]
627	East Gate Lynn, Ruckhope Burn	Showing relation of 'Little Whin Sill' to 'Main' limestone [E]
628	East Gate Beck . . .	Waterfalls in alternating beds of limestone and shales (Yoredale series) [E]
630	Falcon Clints, Teesdale .	Whin Sill, resting on limestone [E]

Size 8 × 6 *inches.*

Regd. No.		
685	Coast north of Marsden .	'Breccia gash,' Magnesian limestone
686	„ „ .	'Fault breccia'; bed of flexible limestone
687	Marsden Bay . . .	Fall of rock; bed of flexible limestone at top of cliff
688	Suter Point . . .	Concretionary limestone
689	„ „ old quarry .	'Cannon ball' concretions
690	Marsden, new quarry .	Bedding planes passing through matrix and concretions
691	Marsden Rock . . .	Sea-stack; Magnesian limestone

GLAMORGANSHIRE.

Photographed by C. J. WATSON, *Acock's Green, Birmingham.* *Size* 6 × 4 *inches.*

633–641	Penarth-Lavernock . .	Series of nine views showing sections of Penarth beds, &c., from Penarth Head to Lavernock

MERIONETHSHIRE.

Photographed by G. J. WILLIAMS, *F.G.S., Higher Grade School, Blaenau, Ffestiniog.* *Size* 6 × 4 *inches.*

603	Foel, Tanygusian, Ffestiniog	Intrusion of 'granitite' into Tremadoc rocks

NORTHUMBERLAND.

Photographed by E. J. GARWOOD, *Newcastle-on-Tyne.* (*Negatives placed with* Messrs. ANDY & RUDDOCK, *Tynemouth.*) *Size* 8 × 6 *inches.*

692	North bank of R. Tyne, between North Shields and Tynemouth	Boulder clay, showing landslip and gullies
693	„ „ .	Boulder clay, resting on Coal Measure sandstone
694	„ „ .	Boulder clay and ironstone concretions
695	„ „ .	Boulder clay, resting on brecciated sandstone
696	„ „ .	Boulder clay, resting on contorted sandstone
697	„ „ .	Boulder clay showing joint
698	„ „ .	Fault traversing coal seams
699	Cullercoats. . . .	Coal Measure sandstone and shales, with cave on coast

SHROPSHIRE.

Photographed by A. C. NICHOLSON, *F.G.S., Oswestry.* *Size* 8 × 6 *inches.*

591–592	Gloppa, near Oswestry .	Contorted glacial drift, sands, and gravels
593	„ „ .	Sandpit in drift
594–595	„ „ .	Esker ridge
596–597	„ „ .	Surface of Esker ridge

Yorkshire.

Photographed by H. Hamilton, *Clapham, near Lancaster.* *Size* 12×10 *inches.*

Regd. No.		
604	Clapham Cave, near Ingleborough	Stalactites in interior
605	„ „	The 'Great Pillar'
606	„ „	Deposits of stalagmite
607	„ „	The 'Stalactite Gallery'
608	„ „	The 'Jockey Cap'
609	„ „	The 'Chandelier'

Photographed by E. J. Garwood, *F.G.S., Newcastle-on-Tyne.* *Size* 8×6 *inches.*

629	Teesdale	Inclusion of shales and limestones in Whin Sill

Photographed by Valentine & Sons, *Dundee.* *Size* 8×6 *inches.*

590	Stump Cross Cavern, Pateley Bridge	(11,948) Stalactites in interior

SCOTLAND.

Argyle.

Photographed by Wm. Ellison, 2 *Balhousie Street, Perth.* (*Per* Henry Coates, *F.R.S.E., Perthshire Society of Natural Science.*) *Size* 8×6 *inches.*

642	Island of Kerrera, opposite Oban	Volcanic rocks (Old Red Sandstone), resting on slates

Photographed by Valentine & Sons, *Dundee.* *Size* 12×10 *inches.*

644	Fingal's Cave, Staffa (546)	Basaltic columns
645	'Old Man of Storr,' Skye (591)	Sea stack
646	'Needle Rock,' Quiraing (598)	„
647	Carsaig Arches, Mull (1,440)	Volcanic rocks

Orkneys.

Photographed by Valentine & Sons, *Dundee.* *Size* 12×10 *inches.*

648	North Golton Castle, Stromness (10,406)	Marine denudation

Perthshire.

Photographed by Wm. Ellison, *Perth.* (*Per* Henry Coates, *F.R.S.E., Perthshire Society of Natural Science.*) *Size* 8×6 *inches.*

643	River Tay, below Stanley	Trap dyke crossing river

(See paper by R. Dow, 'Transactions,' Perthshire Soc. Nat. Sci. vol. i.)

IRELAND.

Co. Antrim.

Photographed by J. Brown, *Belair, Windsor Avenue, Belfast.*
Size 6 × 4 *inches.*

Regd. No.		
656	Fair Head	Marine denudation
657	Much Island . . .	„

Photographed by Miss M. K. Andrews, 12 *College Gardens, Belfast.*
Size 6 × 4 *inches.*

674	Hills Port Island, Magee (52)	'The Goblins,' basaltic cliff

Co. Donegal.

Photographed by J. Brown, *Belair, Windsor Avenue, Belfast.*
Size 6 × 4 *inches.*

649–651	Tory Island . . .	Marine denudation
652–653	„ . . .	Horn's Head
654	Lough Swilly . . .	Dumree Head
655	„ . . .	Glengad Head

Co. Down.

Photographed by J. Brown, *Windsor Avenue, Belfast.*
Size 6 × 4 *inches.*

658	Slope of Slieve Berniagh Mourne Mountains	Granite boulders
659	Spellack Cliff, Slieve Wheel More	
660	North summit of Slieve Birnon, Mourne Mountains	Effects of wind erosion
661	Scotch rocks, near Blue Lake, Mourne Mountains	

Photographed by Miss M. K. Andrews, 12 *College Gardens, Belfast.*
(*Enlargements marked* E.)

675	Scrabo Hill (53) . .	Trias penetrated by dykes [E]
676	„ (54) . .	Vertical dyke [E]
677	„ (55) . .	Horizontal dyke [E]
678	„ (56) . .	Southern continuation of horizontal dyke. Size 6 × 4 inches
679	„ (57) .	Continuous section of No. 1 quarry—east and west. Size 10 × 6 inches, panoramic view

Co. Londonderry.

Photographed by Miss M. K. Andrews, 12 *College Gardens, Belfast. Size* 6×4 *inches.* (*Enlargements marked* E.)

Regd. No.		
662–663	Downhill Cliff (35, 46) .	Basalt, with ochreous bands [662 E]
664–665	Downhill Cliff, Temple rocks (36, 37)	Seastack; 'Backannaboe' (The Tether Stake) [E]
666	Portrantage Valley (38) .	Basalt [E]
667	Umbra (39) . . .	Joint in chalk
668	Umbra, Piper's Cave (40) .	Chalk
669	Umbra, Gap of Carnowery (41)	Chalk; ochreous conglomerate; basalt
670	Downhill Strand (42) .	Chalk and basalt; part of northern margin of basaltic plateau
671–672	Castlerock (43, 44) . .	Basalt and ochreous bands
673	„ (45) . .	Columnar basalt

Microscopic Rock-Sections.

Photographed by Dr. Henry Stolterfoth, *M.A., Chester.* (*Lantern slide.*)

700 Foraminifera, Denbighshire limestone

Photographed by J. J. H. Teall, *M.A., F.R.S.*, 28 *Jermyn Street, London.* (*Per* Aubrey Strahan, *M.A., F.G.S.*)

Series of photographs of microscopic organisms from the Phosphatic Chalk of Taplow, Berkshire.

Regd. No.	
610–612	Foraminifera, ×30; ×35
613	Chalk, washed in water
614	Foraminifera and *Inoceramus* prisms
615	Coprolites ×18
616	Fragments of scales, ×100
617–618	„ fish bone, ×80; ×135
619	„ fish bone bored by fungus, ×90
620	„ scale bored by fungus, ×160

Ninth Report of the Committee, consisting of Professor T. Wiltshire (*Chairman*), Dr. H. Woodward, *and* Professor T. Rupert Jones (*Secretary*), *on the Fossil Phyllopoda of the Palæozoic Rocks.* (*Drawn up by* Professor T. Rupert Jones.)

Eight reports by this Committee have been handed in and printed, the last in 1890. Part I. of the 'Monograph on the British Fossil Phyllopoda,' by Professor T. Rupert Jones and Dr. H. Woodward, published by the Palæontographical Society, contained twelve plates, illustrating thirty-nine species, belonging to four genera of *Phyllocarida* (*Ceratiocaridæ*) therein described. Part II. of that Monograph is now finished,

and has five plates of twenty-eight species in seven genera (including some of both the bivalve and the univalve *Phyllocarida*).

The genera here treated of are *Hymenocaris*, *Lingulocaris*, *Saccocaris*, *Caryocaris*, *Aptychopsis*, *Peltocaris*, *Pinnocaris*, and *Discinocaris*.

I. Of *Hymenocaris* we know of only two species, both British, namely, (1) *H. vermicauda*, Salter, very common in some beds of the Lingula-flags in North Wales; and (2) *H. lata*, Salter, represented by a unique and distorted specimen from the same strata.

II. Of *Lingulocaris* there are (1) *L. lingulæcomes*, Salter; (2) *L. siliquiformis*, Jones; and (3) *L. Salteriana*, T. R. J. and H. W. These are from the Cambrian of North Wales.

III. *Saccocaris major*, Salter, from the Lingula-flags, and *S. minor*, T. R. J. and H. W., from the Arenig series, are described and figured.

IV. *Caryocaris Wrightii*, Salter, and the thinner *C. Marrii*, Hicks, from the Skiddaw slates of Westmoreland, are fully treated of; and it is suggested that the latter form is possibly due to a sexual difference.

V. Of *Aptychopsis* we have recognised thirteen species, mostly British: 1. *A. prima*, Barrande, with its varieties *longa* and *secunda*, all Bohemian. 2. *A. Barrandeana*, sp. nov., and its variety *brevior*, nov. 3. *A. cordiformis*, sp. nov. 4. *A. lata*, sp. nov. 5. *A. glabra*, H. W. 6. *A. Wilsoni*, H. W. 7. *A. Salteri*, H. W. 8. *A. Lapworthi*, H. W. 9. *A. ovata*, sp. nov. 10. *A. subquadrata*, sp. nov. 11. *A. angulata* (Baily). 12. *A. oblata*, sp. nov.

Nos. 5 and 8 are probably represented among the several figures of various forms of '*Aptychopsis prima*' given by Barrande in his 'Syst. Silur. Bohême,' vol. i., Supplement, 1872, plate xxxiii.

Nos. 10 and 11 are from the Silurian of Ireland; the others (excepting No. 7, from South Wales) are from the Moffat series of South Scotland.

VI. Three species of *Peltocaris* are (1) *P. aptychoides*, Salter; (2) *P. anatina*, Salter; (3) *P. patula*, sp. nov.

Like *Aptychopsis*, *Peltocaris* is an Upper-Silurian British form, with some representatives in the Middle Silurian.

VII. *Pinnocaris Lapworthi*, Etheridge, jun., a rare Silurian form, is known in Ayrshire and Westmoreland.

VIII. Of the round subconical tests, undivided except by the triangular nuchal notch, *Discinocaris* gives four species, all from the Upper or Middle Silurian of South Scotland and Westmoreland: 1. *D. Browniana*, H. W. 2. *D. ovalis*, sp. nov. 3. *D. undulata*, sp. nov. 4. *D. gigas*, H. W.

The British specimens here referred to belong to—(1) the British Museum; (2) the Museum of Practical Geology and Geological Survey of Great Britain; (3) Museum of the Geological Survey of Scotland; (4) Museum of the Geological Survey of Ireland; (5) Woodwardian Museum, Cambridge; (6) Museum of the Owens College, Manchester. The authorities of these institutions have courteously given us facilities (by loan or otherwise) for studying the specimens. For the loan of a large series we owe thanks to Mr. D. J. Brown, of Moffat, and for others to Dr. C. Lapworth, of Birmingham. The late Mr. James Dairon, of Glasgow, also obligingly lent us some specimens.

The *Pinacaridæ* (*Dithyrocaris*, &c.) have next to be described and figured in detail; and further descriptions and figures are required of the *Ceratiocaridæ*, for which the Committee have accumulated much material. Mr. J. G. Williams, F.G.S., of Ffestiniog, has lent the Committee a large

series of North-Welsh Phyllocarids, including *Hymenocaris* and other genera, which will require careful study.

The chief additions to published information about the Palæozoic *Phyllopoda* are—

1. Some notes on the Devonian *Estheria membranacea*, with a figure and description of an oblong variety, showing the concentric riblets and interstitial ornament, in the 'Geological Magazine,' 1890, pl. xii., fig. 9, and 1891, p. 50.

2. In his Mémoire sur la Faune du Grès Armoricain ('Annales Soc. Géol. du Nord,' vol. xix., 1891) Dr. C. Barrois, after noting (pp. 147 and 149) that the little fossil, quoted by MM. de Tromelin and Lebesconte as *Cytheropsis subtestis* ('Report Assoc. Franç. Congrès de Nantes,' 1875 [1876], p. 23) is a *Primitia*, near *P. debilis*, Barrande, proceeds to treat of *Myocaris lutraria* at pp. 220 and 221, pl. v., fig. 4; and describes a small caudal spine, probably of a *Ceratiocaris*, p. 221, pl. v., fig. 3; also an abdominal segment and caudal appendages (style and stylets) of a new Ceratiocarid, namely, '*Trigonocarys*' [*Trigonocaris*] *Lebescontei*, nov. gen. et sp., pp. 222–226, pl. v., figs. 5 and 6; all from Guichen.

3. Description of Fossils from the Palæozoic Rocks of Ohio, by R. P. Whitfield ('Annals New-York Acad. Science,' vol. v., December 1890):—

Page 562. PHYLLOPODA, p. 563, *Echinocaris*, Whitfield ('Amer. Journ. Sci.,' 1880).

At pp. 564–5 seven groups of *Ceratiocaridæ* are defined, according to their segments, &c.

Page 565. *Echinocaris sublevis*, Whitfield, 1880, pl. xii., figs. 12–14.

Page 567. *E. pustulosa*, Whitfield, 1880, pl. xii., fig. 13.

Page 568. *E. multinodosa*, Whitfield, 1880, pl. xii., fig. 16.

From the Erie shales of Ohio (=Portage and Chemung groups of New York State). *See* 'Amer. Journ. Sci.,' 3rd ser., vol. xix., p. 36, &c., 1880.

At p. 572. *Aristozoe canadensis*, Whitfield, 1880, pl. xii., figs. 17 and 18, from the Trenton formation in the Ottawa basin of Canada. Locality unknown. Introduced for comparison.

See also 'Report British Association' for 1885 [1886], p. 35.

4. The illustrated description of *Discinocaris Dusliana*, by Professor O. Novák, in the 'Geological Magazine,' 1892, p. 148. This is one of three specimens found by Herr Dusl in the strata of the 'Colonie Haidinger,' Bohemia, and referred to by Mr. J. E. Marr, F.R.S., in the 'Quart. Journ. Geol. Soc.,' vol. xxxvi., 1880, p. 617.

5. The fauna of the Lower Cambrian, or Olenellus Zone, by Charles D. Walcott ('Tenth Annual Report of the U.S. Geological Survey,' 1891 ?); *Protocaris Marshi*, Walcott, p. 629, pl. lxxxi., fig. 6 ('Bull. U.S. Geol. Surv.,' No. 30, 1886, p. 148, pl. xv., fig. 1):—an obscure subquadrate test (?), with a many-segmented body and a furcate caudal appendage (*see* our Seventh Report for 1889 [1890], p. 64).

Report of the Committee, consisting of Dr. H. Woodward, Mr. G. R. Vine (*Secretary*), Professor T. Rupert Jones, *and* Dr. H. C. Sorby, *appointed for the completion of a report on the Cretaceous Polyzoa.* (*Drawn up by the Secretary.*)

I. Upper-Cretaceous Polyzoa (British area only).

In a previous report on Cretaceous Polyzoa [1] I dealt with the stratigraphical distribution of the fossils which had been found in the lower beds of the Upper Cretaceous series, and in the Neocomian beds below. Last year (1891), at the Cardiff Meeting of the British Association, I contributed a paper on the Polyzoa of the Zones of the Upper Chalk,[2] in which I referred to certain peculiarities of some of the Polyzoan fauna derived from the British Senonian rocks, which had been noticed in the course of my investigations. These peculiarities seemed to merit something more than a passing remark, and I partly expressed an opinion that, in all probability, if the different zones of the Chalk were carefully worked, and the Polyzoan fauna studied, much light might be thrown upon the zonal distribution of Polyzoa in Cretaceous rocks, both British and Continental. In the present report I have endeavoured to carry out my original design, and I believe I have now catalogued all the British species which have been recorded up to date. Had it not been for the willing help of personal friends, this would have been impossible. To Mr. Gamble, of New Brompton, Kent, I tender my most sincere thanks for placing before me his fine collection of Chatham Polyzoa, and for the free gift of fragments derived from the Chalk and from the 'Flint-meal,' which have proved to be of the highest value in the compilation of this report. By means of this help the Chatham Chalk has been worked so thoroughly that this section of my labours must be regarded as the type of all the others that will follow.

In the report already referred to I drew attention to the fact that in Mr. Etheridge's lists of genera (with specific indications), published in the second volume of Professor Phillips' 'Manual of Geology,'[3] only sixty-one British species are recorded as derived from the whole of the Upper Cretaceous rocks. This is sixteen more than were given by Professor Morris in the 'Catalogue of British Fossils' (ed. 1854). In Table VIII., p. 333, vol. ii. of Professor Prestwich's 'Geology,' 1888, the 'Polyzoans' from the Chalk, Upper Greensand, and Gault are tabulated as '80,' or about the same 'specific' proportion as given by Mr. Etheridge, '59 genera and 114 species,' if we leave out the 34 species found in the Neocomian rocks. This, then, as there have not been any additions to the Cretaceous Polyzoan fauna subsequent to those dates, must be taken as the status of our knowledge since the issue of the admirable 'Catalogue of British Fossils' by Professor Morris in 1854.

Of public collections of Upper-Chalk Polyzoa I am acquainted with a few only. The fine series in the British Museum (Natural History) I have recently examined, but it is now undergoing rearrangement. The series

[1] British Association Report on 'Cretaceous Polyzoa,' 1890.
[2] *British Association Reports*, 1891, p. 656.
[3] Ed. 1885, pp. 589–90.

contains Lonsdale's types, besides which there are selections from the cabinets of Mr. Woodward (Norfolk Polyzoa), Dr. Bowerbank, and others. There is also a good collection in the Museum of Practical Geology, Jermyn Street, derived from several British localities.

In the 'Paléontologie Française : Terrains Crétacés,' vol. v., 1850–52, d'Orbigny gives the sum-total of the Senonian Bryozoa of France as follows (p. 1082) :—

Bryozoaires Centrifugines (*Cyclostomata ?*), genera 115 ; species 300.
„ Cellulines (*Cheilostomata ?*), genera 54; species 547.

In Dr. Friedrich von Hagenow's 'Die Bryozoen der Maestrichter Kreidebildung,' published in 1851, about 180 species are described and illustrated as derived from the Maestricht Chalk. In this work Dr. Hagenow re-describes the whole of Dr. Goldfuss' Cretaceous Bryozoa, and breaks up the limited classification of the group as given in 'Petrifacten,' and redistributes the restricted genera adopted by Goldfuss in that work.

Previous to the publication of these two leading palæontological works, which deal with the Bryozoa in detail, there were others of less note, but all the Cretaceous species which had been described or catalogued before 1850 and 1852 are fully recorded by d'Orbigny in the introductory notes which preface the specific descriptions in vol. v. of the 'Paléontologie Française.'

In 1886 Dr. Ed. Pergens and A. Meunier published their joint paper, 'La Faune des Bryozoaires Garumniens de Faxe,' [1] in which nearly 60 species of Bryozoa are recorded from this horizon, and eight of these are either new species or new varieties. Some years since Professor J. Judd made me a present of a large block of the Faxoe Limestone which he brought with him from Denmark, and by carefully breaking up the mass and then washing the finer débris I was able to pick out a quantity of these delicate fossils. I have therefore been able to verify most of the forms described by the authors, and I find that at least five or six other species, not given by Dr. Pergens, may be added to the Faxoe list.

This little monograph, then, is extremely valuable to the student of Upper-Cretaceous Polyzoa on account of the very wide range, from Neocomian to Recent, which the authors assign to the species indicated by them. No doubt the range of variation in many of our so-called species is only partially considered; hence the desire on the part of some of our Continental palæontologists to reduce to mere synonymy a large number of the generic and specific names of authors, and of d'Orbigny in particular. Whether palæontological research will be retarded or helped by the wholesale destruction of specific names, remains to be seen. On the other hand, the tendency of certain authors to increase the difficulties of the student by the introduction of new generic terms whenever slight variations of the Polyzoan zoarium present themselves is much to be deplored.

In 1887 Dr. Th. Marsson's valuable monograph was published, 'Die Bryozoen der Weissen Schreibkreide der Insel Rügen,' [2] and this work adds considerably to our knowledge of Upper-Cretaceous Polyzoan forms. In his descriptive text the author not only creates new divisional and new family names, but many new genera and species besides. It is very

[1] *Ann. de la Soc. Royale Malacol. de Belgique*, tome xxi.
[2] *Druck und Verlag von Georg Reimer*, Berlin, 1887.

evident that Dr. Marsson's attention has been, to a large extent, concentrated upon the Polyzoa of this Cretaceous horizon more particularly. This, however, I look upon as an advantage, because we have in this work a monograph, which is well illustrated, of the Rügen Bryozoa, and Dr. Marsson says that examples of the whole of the species described by him are in his own cabinet.[1]

There is still another paper which must not be passed over in silence. In 1889 Dr. Pergens published the first part of his 'Revision des Bryozoaires du Crétacé, figurés par d'Orbigny.'[2] In this work Dr. Pergens accepts to some extent the divisions of Dr. Marsson, but the revision is chiefly valuable to the student of Cretaceous Polyzoa on account of the masterly way in which the author has dealt with the specific creations of d'Orbigny, and that, too, with d'Orbigny's examples before him, the whole of which are now preserved in the Paris Museum.

II. Classification of Cretaceous Polyzoa.

In the preceding pages I have given, as far as I was able, the status of our present knowledge of British Upper-Cretaceous Polyzoa. It is very evident, judging by the identifications of the several authors whose authorities are quoted in the following lists, that the 'Palæontology of France,' vol. v., is to a large extent the real source of their information on Cretaceous Polyzoa generally. Long before d'Orbigny favoured us with the productions of his facile pen, Dr. Mantell ('Medals of Creation,' 1844) and Mr. W. Lonsdale gave some fairly faithful delineations of British Polyzoa (Dixon's 'Geology of Sussex,' 1850).

The classification originally formulated by d'Orbigny was so framed as to include recent as well as fossil species, but it is evident, judging from the later work of the author, that d'Orbigny himself felt that this task was a difficult one. Nevertheless, we owe to this effort on his part the very full and valuable synopses and lists which have already been referred to. It is impossible, therefore, to accept the classification of d'Orbigny as a classification; but if we cast about for one less elaborate, I am not sure that we shall meet with any that may be considered entirely faultless. The classifications of Mr. Hincks or Mr. Busk, modified by the researches and descriptions of Mr. A. W. Waters, must, for the present at least, serve the purposes of this report. Further on I have given my reasons for adopting some of the generic and specific names of d'Orbigny in preference to the more modern ones when arranging the Cheilostomata. In the arrangement of the Cyclostomata I have followed, though not slavishly, the generic and specific distinctions of Dr. Pergens, which were tabulated on pp. 279, 280 of my former report, 1890.

III. The Chatham Chalk and its Polyzoan Fauna.

Professor Prestwich ('Geology,' vol. ii., p. 297), with characteristic brevity, refers to the zonal divisions of the Chalk 'which have of late years been worked out in considerable detail, and are found to coincide very closely with those previously established for the Chalk of the north

[1] Since this was written I have heard of Dr. Marsson's death. Probably the Polyzoa collected by him will be preserved in one of the German museums.

[2] *Bull. de la Soc. Belge de Géol. et Paléontologie*, tome iv.

of France. Between the Isle of Thanet and Folkestone the Chalk, according to Whitaker, Hébert, Price, and others, is divisible into several groups and zones.' Very few of the sections, however, given by Professor Prestwich contain the whole of the beds found in British Senonian rocks. In the neighbourhood of Salisbury, according to Mr. E. Westlake,[1] we have something like a typical succession; consequently I shall take this as a preface to other zonal sections which will follow, and indicate the differences by the letters A, B, C, D, E, (F).

A. Zone of *Belemnitella mucronata*. Thickness about 100 feet.
B. ,, ,, *quadrata*. ,, ,, 100 ,,
C. ,, *Marsupites testudinarius*, and *Holaster pilula*. Thickness about 150 feet.
D. Zone of *Micraster cor-anguinum*. Thickness about 100 feet.
E. ,, ,, *cor-testudinarium*. ,, ,, 50 ,,
(F.) Base (Turonian?) zone of *Holaster planus*. Thickness about 15 feet.

In East Kent the zonal succession of the Upper Chalk is as follows:—

D. Chalk with flints. Zone *Micraster cor-anguinum*, Margate.
E. ,, ,, ,, ,, *cor-testudinarium*, Ramsgate, Broadstairs.
(F.) Chalk with flints. Zone *Holaster planus*, St. Margaret.

In the Isle of Wight, according to Dr. Ch. Barrois, there is a very large development of Chalk of one particular zone (D).

A. White Chalk. Zone *Belemnitella mucronata*, 265 feet.
D. ,, ,, ,, *Micraster cor-anguinum*, 525 feet.
E. ,, ,, ,, ,, *cor-testudinarium*, 165 feet.
(F.) ,, ,, ,, *Holaster planus*, 65 feet.

In Surrey, according to Mr. Caleb Evans (Prestwich, 'Geology,' vol. ii., p. 297), the section of the line from Croydon through the North Downs shows the following succession in about the thickness of 250 feet:—

D. Zone of *Micraster cor-anguinum*, Purley beds.
E. ,, ,, *cor-testudinarium*, Riddlesdown beds.
(F.) ,, *Holaster planus*, Kenley beds.

In Buckinghamshire and Cambridgeshire (Prestwich, p. 298) only the base of the Upper Chalk is given, and characterised as

(F.) Zone of *Micraster cor-bovis*. Chalk with flints.
The zone of *Holaster planus* is regarded as the topmost division of the Middle Chalk.

The subdivisions of the Chalk in Yorkshire, according to Professor Phillips and Mr. Blake (Prestwich, p. 298), are as follows. The thickness of the strata characterised is about 500 feet.

[1] 'Outlines of the Geology of Fordingbridge, &c.,' *Mitchell's Fordingbridge Almanack and Directory*, 1889, separate copy, p. 7.

A. Zone of *Belemnitella mucronata*, &c. Chalk without flints.
D. „ *Micraster cor-anguinum*, &c. Chalk with flints.

By way of contrast, it will be only necessary for me to quote two of the many palæontological divisions of the Continental Chalk on account of the correlation of these with our own British sections. In north-western France the zonal divisions are, to a large extent, based on the stratigraphical divisions of d'Orbigny, and are as follows: 1, Danian; and 2, Senonian:—

1. Danian.

Zone of *Nautilus Danicus*.

2. Senonian.

A. Zone of *Belemnitella mucronata* (Chalk with flints), Meudon.
B. „ „ *quadrata* (Chalk with flints), Epernay.
D. „ *Micraster cor-anguinum*, Chalk cliff east of Dieppe.
E. „ „ *cor-testudinarium*, Chalk cliff west of Dieppe.
(F.) Here, again, the zone of *Holaster planus* forms the top bed of the Turonian series.

In all probability the Upper Chalk found in the neighbourhood of Chatham may be placed in the zones marked D and E in the above sectional divisions. Chatham is superficially separated from the Margate and Ramsgate outcrop by the supervening London Clay, but the Upper Chalk must have been continuous from the Essex outcrop to Gravesend, Chatham, and the Isle of Thanet; also from Sussex to Dieppe.

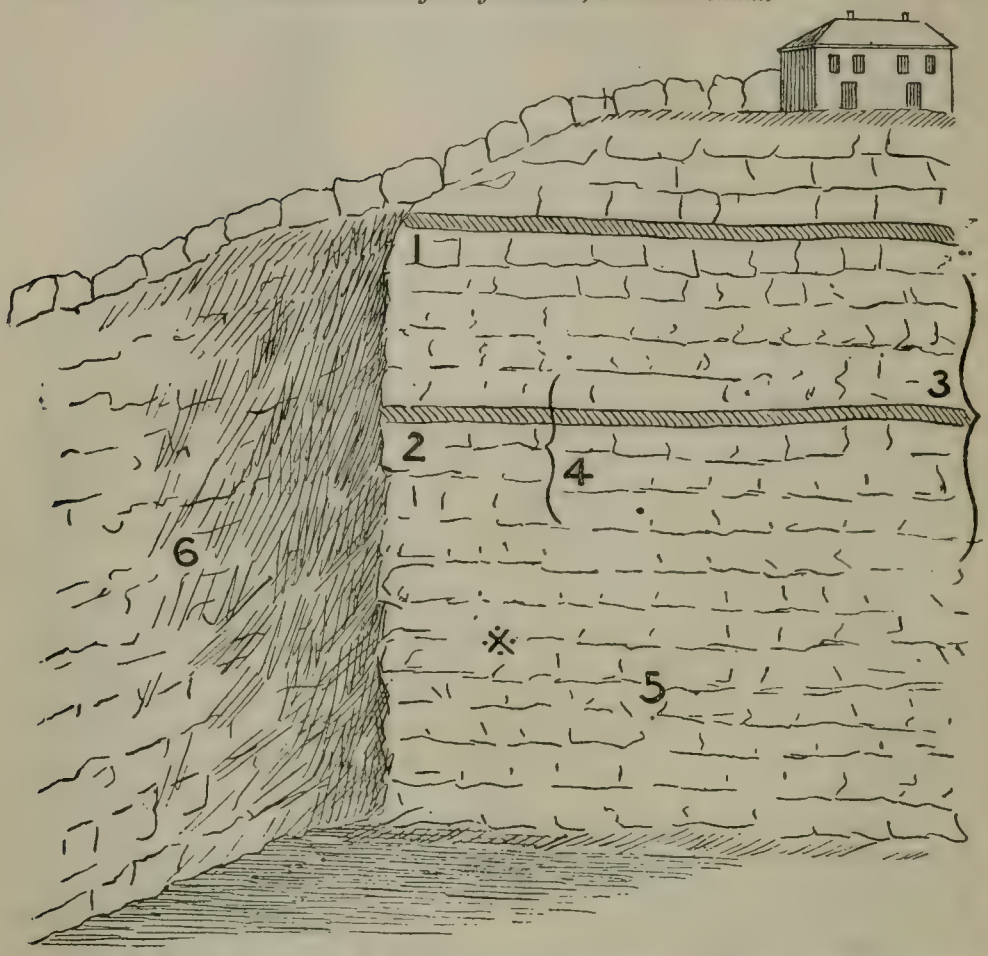
It is impossible for me, of my own knowledge, to give any information respecting the geology of Chatham and its vicinity. When the Polyzoa, which will be elaborately dealt with presently, were sent to me by Mr. Gamble, I asked him particularly to give some account of the zones in which the more characteristic forms were found. In reply to this request I received sketches of the several pits in which the Polyzoan material was most abundant. [Since this was written I have spent three days with Mr. Gamble—purposely in the interest of this report—to see for myself the evidences on which the following remarks are based. I have seen the various sections; collected material—especially the 'Flint-meal' referred to further on; and, moreover, I have carefully examined Mr. Gamble's private collection of Polyzoa, containing duplicates of nearly all the forms sent to me from time to time.]

Some of the adherent species of Polyzoa, such as *Stomatopora*, *Proboscina*, and *Diastopora*, were found encrusting many fossils; such as *Micraster cor-anguinum*, *Echinocorys*, and other echinoderms; but the most abundant of the forms described were found in the 'Flint-meal,' which was derived from the hollows of flints. To the protective agency of this meal we owe the preservation of the more delicate branching Polyzoa, together with a varied assortment of the spicula of sponges, Foraminifera, Entomostraca, and other minute organisms.[1]

[1] Speaking of the cavity and the so-called 'meal' found in the now celebrated Horstead Flint, Dr. G. Jennings Hinde suggestively remarks:—'The cavity appeared to have been completely inclosed by the flint, which had thus hermetically sealed up in its interior and preserved unharmed from mechanical injury a small portion of the mud of the Cretaceous ocean.'—*Fossil Sponge Spicules*, &c., p. 4. Munich, 1880. G. J. Hinde.

Mr. Gamble obtained Polyzoa from several of the pits opened in the Chatham district, but these were generally found in very restricted horizons. I have sectional sketches of five of these pits, all of which I have since visited, and in one (see annexed sketch) the strata appear to be horizontal, being cut along the strike. Very high up or towards the top the stratum is marked by two iron-stained bands. Just below the highest

Section showing Polyzoa Zone, Chatham Chalk.



Section A, on the south side of Chatham, about 70 feet high. 1. Upper iron-stained band referred to in the text. 2. Lower iron-stained band. 3. Polyzoa zone. In this section very few of the dendroid species were found. 4. A bed of *Ananchytes* and *Spatangus* completely invested by Serpula, Membranipora, Proboscina, and Stomatopora, &c. 5. Showing the horizontal bedding. At * many good *Ventriculites* were found in the zone indicated. 6. Showing dip north-west. (Contributed, with information and examples of the species indicated, by Mr. Gamble.)

band the Polyzoa zone begins, but the life-climax—if I may be allowed the term—is reached just above and just below the lowest band. In the section now under description this position is indicated by the figure 4, which, Mr. Gamble says, consists of a bed of *Ananchytes* and *Spatangus* completely invested by Membraniporæ, Serpulæ, and adherent forms of Cyclostomata, such as Stomatopora, Proboscina, Diastopora, and other forms. When searching in other pits for Polyzoa, it was found that the

presence of these two iron-stained bands was indicative of the position where the Polyzoan fauna might be found; but in some of the pits the bands were either too high or too low, or, in other words, this zonal division was not a marked feature in the rocks exposed, and the yield of forms consequently suffered. Nearly the whole of the Polyzoa sent to me were derived from one particular pit, but similar forms, though not so abundant, are found in other pits whenever the sectional or zonal lines indicated above were exposed. After passing a little section which yielded a few Polyzoan fragments, the Luton valley widens, the escarpment is not so deep, and the Polyzoa zone is lost under the bed of the valley, where it is not possible to meet it again except by boring. Mr. Gamble says it must not be supposed that the Polyzoa are wholly confined to the zone which is bracketed in the sketch. Polyzoa will be, and have been, found both above and below the iron-stained bands; but the greater number are really found in the division or zone indicated.[1]

IV. Catalogue of Polyzoa found in the Chatham Chalk.

(With full references to d'Orbigny and others).

Sub-order Cyclostomata.

1825. Genus Stomatopora (Uniserial), Bronn, d'Orb., 'Terr. Crét.,' p. 833.

1. Stomatopora Dixoni, sp. n. (=*Alecto gracilis*, Lonsd., 'Foss. Sussex,' p. 269, pl. 18A, figs. 1–1*c*).

This is not the *Alecto gracilis* of either Edwards or Bronn (see d'Orb., 'Terr. Crét.,' p. 843, pl. 758, figs. 17, 18); but, as the form is abundant in the Chatham Chalk, I have thought it best to rename Lonsdale's species.

2. Stomatopora ramea, Blainv. ('Terr. Crét.,' p. 842, pl. 630, fig. 12, non Synonyms of d'Orb.).
3. „ granulata, Edw., var. gigantea, Perg., 'Revis. des Bryoz.,' p. 330.
4. „ gracilis, Edw., 'Ann. des Sc. Nat.,' 9, p. 207 (see d'Orb., 'Terr. Crét.,' p. 843).

1826. Genus Proboscina, Audouin (d'Orb., 'Terr. Crét.,' p. 844).

5. Proboscina cornucopiæ, d'Orb., 'Terr. Crét.,' p. 855, pl. 634, figs. 7–9.
6. „ cornucopiæ, var. eximia, var. n. (near *P. echinorum*, d'Orb.), only more delicate (see pl. 633, fig. 12).
7. „ elevata, d'Orb. var. (allied to *Reptotubigera id.*, d'Orb., *l. c.*, p. 755, pl. 760, figs. 1–3).
8. „ Wetherelli, Morris (=*Diastopora*, Lonsd., 'Foss. Sus.,' pl. 18A, fig. 3).
9. „ ramosa, Michelin, *Diastopora*, Lonsd., 'Foss. Sus.,' pl. 18B, figs. 1–1*b*.

[1] Since this was written I have collected material from other pits for the purpose of comparison, and I can verify Mr. Gamble's remarks.

1852. Genus Reptotubigera, d'Orb., 'Terr. Crét.,' p. 751.

10. Reptotubigera ramosa, d'Orb., *l. c.*, p. 754, pl. 751, fig. 2.
11. ,, ,, var. (*a*) irregularis, nov.
12. ,, ,, var. (*b*) disciformis, nov.
13. ,, elegans, sp. n.

1816. Genus Tubulipora (pars), Lamarck. See Hincks' 'Brit. Mar. Polyz.,' 1880, p. 442, non *Reptotubigera*, d'Orb., which is one of Mr. Hincks' Synonyms.

14. Tubulipora Chathamensis, sp. n.
15. ,, ,, var. ornata, var. n.

1821. Genus Diastopora, Lamouroux (*Berenicea*, d'Orb.).

16. Diastopora papillosa, Reuss. (Perg., 'Revis. des Bryoz.,' p. 334, pl. xi., fig. 6, non fig. 9).
17. ,, papillosa, forma echinata (*Berenicea*), d'Orb., 'Terr. Crét.,' *l. c.*, p. 868, pl. 641, figs. 1, 2.
18. ,, grandis, d'Orb. (*Berenicea*, *id.*, d'Orb.), *l. c.*, p. 866, pl. 639, figs. 4, 5.
19. ,, congesta, d'Orb., pl. 640, fig. 2 only (=*D. papillosa*, (?), Perg., *l. c.*, *ante*).
20. ,, littoralis, d'Orb., *l. c.*, p. 867, pl. 640, figs. 7, 8.

1821. Genus Idmonea, Lamx. =*Crisina* (pars), d'Orb., 'Terr. Crét.,' *l. c.*, p. 728; Pergens, 'Revis. des Bryoz. du Crét.,' p. 342.

21. Idmonea unipora, d'Orb., 'Terr. Crét.,' p. 737, pl. 613, figs. 1–10; Perg., 'Revis.,' p. 342.
22. ,, subgracilis, d'Orb., 'Terr. Crét.,' p. 738, pl. 614, figs. 6–10; Perg., 'Revis.,' p. 345.
23. ,, francorum, Pergens, 'Revis. des Bryoz.,' p. 343, pl. xiii., fig. 1.
24. ,, pseudodisticha ? var. (*a*), var. (*b*). See Perg., 'Revis.,' p. 348.
25. ,, dorsata, Hag., 'Bryoz. Maestr. Kreideb.,' p. 30, pl. 2, fig. 10.
26. ,, cypris ? d'Orb. (or variety), 'Terr. Crét.,' p. 741, pl. 749, figs. 7–10; Perg., 'Revis.,' p. 349.
27. ,, carantina, d'Orb., 'Terr. Crét.,' p. 734, pl. 748, figs. 1–5; Perg., 'Revis.,' p. 346.

1847. Genus Reticulipora, d'Orb., 'Terr. Crét.,' *l. c.*, p. 903; Pergens, 'Revis.,' p. 354.

28. Reticulipora papyracea, d'Orb., *l. c.*, p. 907, pl. 611, figs. 1–5; pl. 768, figs. 3–10.
29. ,, obliqua, d'Orb., *l. c.*, p. 906, pl. 610, figs. 1–6; pl. 768, figs. 1, 2.

I have seen an example of this species in Mr. Gamble's collection completely silicified. (Pseudomorph in flint.)

30. Reticulipora complanata, Marsson, 'Bryoz. Weiss. Schreibkr. Rügen,' p. 36, pl. 3, fig. 10.

1821. Genus Entalophora, Lamouroux (see Perg., 'Revis. des Bryoz,' p. 358).

In Dr. Pergens' history and characteristics of this genus will be found many details which may be valuable to the general student of recent Polyzoa, as well as the fossil forms found in the Cretaceous rocks; but I question the value of the reduction of the ten species given by d'Orbigny to mere synonyms of *Pustulopora proboscidea*, Edwards (1838), (Perg., 'Revis. des Bryoz.,' p. 359). I cannot, however, wholly reject the evidence brought forward by Dr. Pergens, who has liberally supplied me—for comparison—with many beautiful examples of *P. proboscidea* (Edw.), dredged from 60 fathoms off Capri, Bay of Naples; also examples from the Faxoe Limestone, Denmark, which were fully described in their joint paper (Pergens and A. Meunier), 'La Faune des Bryozoaires Garumniens de Faxe,' 'Ann. de la Soc. Royale Malacol. de Belgique,' tom. xxi., 1886, p. 202). I shall, therefore, indicate by the word 'forma' the abundant variety found in the Chalk of Chatham, at the same time giving the original references to the figures given by d'Orbigny in the 'Atlas.'

31. Entalophora proboscidea typica, Edwards (1838) = *Pustulopora*, *id.* (Perg., 'de Faxe,' pl. x. fig. 1).
32. „ „ ? forma raripora, d'Orb., pl. 621, figs. 1–3.
33. „ „ ? forma Iconensis, d'Orb., pl. 616, figs. 12–14.
34. „ „ ? forma filiformis, d'Orb., pl. 622, figs. 1–4.
35. „ „ ? forma linearis, d'Orb., pl. 622, figs. 5–7.
36. „ „ ? var. rustica, Hagenow, Perg., 'Revis. des Bryoz.,' p. 360.
37. „ geminata, Hag., 'Bryoz. der Maestr. Kreideb.,' p. 20, pl. i., fig. 11.
38. „ clava, d'Orb., 'Terr. Crét.,' pl. 620, figs. 4–5 only.
39. „ madreporacea, Goldf., forma inconstans. d'Orb., 'Terr. Crét.,' p. 786, pl. 754, figs. 15–17; Perg., 'Revis.,' p. 361.

1887. Genus Clinopora, Marsson, 'Bryoz. Weiss. Schreibkr. Rügen,' p. 24.

40. Clinopora costulata, Mars., *l. c.*, p. 24, pl. ii., fig. 2.
41. „ lineata, Beissel. (Marsson, *l. c.*, p. 24, pl. ii., fig. 2, for references.)

1821. Genus Spiropora, Lamouroux (see Pergens, 'Revis. des Bryoz.,' p. 363).

Pergens in his revision of d'Orbigny's labours re-establishes this genus. See his remarks on the well-known species *S. verticillata*, Goldfuss, *l. c.*, pp. 363–365.

42. Spiropora verticillata (?), Goldf. = *Idmonea Comptoniana* (?), Mantell's 'Medals,' vol. i., p. 284, woodcut 64, fig. 14.

I am rather doubtful about the forms in the Chalk of Chatham. The fragments, however, are closely allied to this species.

43. Spiropora macropora, d'Orb.=*Laterotubigera*, *id.*, d'Orb., 'Terr. Crét.,' p. 718, pl. 754, figs. 5–7.
44. ,, micropora, d'Orb. =*Laterotubigera*, *id.*, d'Orb., *l. c.*, p. 719, pl. 754, figs. 12–14.
45. ,, Cenomana, d'Orb. (?), *l. c.*, p. 715, pl. 618, figs. 11–15.

1847. Genus Bidiastopora, d'Orb., 'Terr. Crét.,' p. 798; Perg., 'Revis.,' p. 367.

46. Bidiastopora Mariæ, d'Orb., *l. c.*, p. 804, pl. 755, figs. 13–15.
47. ,, lamellosa (?), d'Orb. (*Elea*), *l. c.*, p. 632.

1852. Genus Sulcocava, d'Orb., 'Terr. Crét.,' p. 1020.

48. Sulcocava sulcata? d'Orb., *l. c.*, p. 1020, pl. 789, figs. 1–3.

1850. Genus Petalopora, Lonsdale, Dixon's 'Geol. Sussex,' p. 285.

[*Zoarium*] 'Tubular, free except at the base; framework [*zoœcia*] composed of vertical laminæ, with an intermediate, foraminated structure; apertures to the visceral or tubular cavities distributed over the whole surface . . .' 'Geol. Sus.,' p. 285,=*Cavea* (pars), d'Orb., 1852, 'Terr. Crét.,' p. 941.

49. Petalopora pulchella (Römer), Lonsd., 'Geol. Sus.,' p. 285, pl. 18A, figs. 7, 7*a*, &c.

Under the name *Heteropora costata*, d'Orb., Dr. Pergens places several of the *Cavea* species of d'Orbigny. As I cannot wholly accept this division, I give Lonsdale's genus in preference, especially so as neither d'Orbigny nor Dr. Pergens seems to recognise the prior claim of Lonsdale: *Petalopora*, Lonsdale, 1850; *Cavea*, d'Orbigny, 1852.[1] In the Chatham Chalk I recognise several fragments of a species similar to the above, so we may regard the synonymy of Dr. Pergens as near the truth; thus *Cavea costata*, d'Orb.=*Petalopora pulchella* (?), may be regarded as a synonym of Lonsdale's species. One difficulty, however, presents itself. *Cavea costata*, d'Orb., 1852, is regarded by the author as the same as *Entalophora costata*, d'Orb., 1850, 'Terr. Crét.,' p. 944, pl. 621, figs. 19, 22. Probably d'Orbigny is correct in his later identification; but, if so, there is no clear evidence of the characters—so fully described by Lonsdale—in his figures. I therefore think that Lonsdale's name should stand, and that the following forms, characterised by d'Orbigny, be regarded as synonyms. I have given the names of those species only which I have been able to identify from fragments found in the Chatham Chalk. For the sake of uniformity I have given all the synonyms separate numbers, as other workers on the Cretaceous Polyzoa may not be inclined to accept my decision on this point:—

[1] See Dr. Pergens, *Revis. des Bryoz.*, pp. 369–372.

50. Petalopora pulchella, forma Clavicavea regularis? 1852, d'Orb., 'Terr. Crét.,' p. 941, pl. 773, figs. 12, 13.
51. „ „ „ Cavea regularis, 1852, d'Orb., *l. c.*, p. 943, pl. 774, figs. 1, 2.
52. „ „ „ „ costata, d'Orb., *l. c.*, p. 944, pl. 774, fig. 4 (non pl. 601, figs. 19–22).
53. „ „ „ „ appendiculata, d'Orb., *l. c.*, p. 944, pl. 774, fig. 5.
54. „ „ „ „ flexuosa, d'Orb., *l. c.*, p. 947, pl. 774, figs. 9–12.

The other forms indicated by d'Orbigny I have not distinguished in the Chatham material.

1834. Genus Heteropora, Blainville.[1]

This genus, as characterised by Dr. Pergens, includes species belonging to the following genera of d'Orbigny:—*Claviclausa*, *Clausa*, *Cavea*, *Clavicavea*, *Sparsicavea*, *Multicrescis*, *Zonopora*, *Multizonopora*, and typical *Heteropora*. The characters of the species found in the Chatham Chalk are so diverse that I feel compelled to make a slight departure from the classification of Dr. Pergens in the special arrangement of this peculiar group of Polyzoa:—

Heteropora, Pergens = *Clausa*, d'Orbigny, 'Terr. Crét.,' p. 893.

55. Heteropora obliqua, d'Orb., 'Terr. Crét.,' p. 895, pl. 623, figs. 18–21.
56. „ irregularis, d'Orb., *l. c.*, p. 897, pl. 624, figs. 9–12; pl. 766, figs. 10–12.
57. „ Francqana, d'Orb., *l. c.*, p. 898, pl. 766, figs. 13–15 (mentioned as being bad in the Paris collection; but the examples are very fine in my Chatham collection).

Heteropora, Pergens = *Sparsicavea*, d'Orb., 'Terr. Crét.,' p. 948.

58. Heteropora Carantina, d'Orb. (Perg., 'Rev. des Bryoz.,' p. 372), 'Terr. Crét.,' p. 950, pl. 775, figs. 1–3.
59. „ Francqana, d'Orb., *l. c.*, p. 951, pl. 775, figs. 4, 6 (figures bad).
60. „ Ligeriensis (= *Multizonopora*, d'Orb.), *l. c.*, p. 927, pl. 772, figs. 4–6.
61. „ variabilis? (*Multicrescis*), d'Orb, *l. c.*, p. 1077, pl. 800, figs. 3–7.

1887. Genus Cavarinella, Marsson.

62. Cavarinella ramosa (?) = *Cavaria ramosa*, Hagenow.

This species appears to be rare in the Chatham Chalk. I have only one very poor example, which I place here for the present.

[1] See Dr. Pergens, *Revis. des Bryoz.*, p. 369.

1852. Genus Bitubigera, d'Orb. (= *Idmonea* (pars), Philippi). 'Terr. Crét.,' p. 748.

This genus was founded by d'Orbigny for *Idmonea* sp., Philippi, derived from No. 26 stage, *Falunien*, for the location of *Bitubigera* (*Idmonea*) *biseriata*, Phil. (1844). No Cretaceous species is recorded by d'Orbigny. Marsson, 'Bryoz. Weiss. Schreibkr. Rügen,' p. 31, adopts the genus for the inclusion of one species, *B. compressa*, Mars., pl. iii., fig. 1. The species now recorded is different from either of the forms cited, but it is very rare in the Chatham Chalk.

63. Bitubigera cribriformis, sp. n.

The zoœcia of this species are disposed, Idmonea-like, in two series obliquely over one-half the zoarium. The interspaces between the rows and the slightly rounded reverse are of a cribriform character. Judging from his figures, Marsson's depicted characters are quite plain.

I have seen a British example closely related to the above characterised as *Idmonea gradata*, but I have followed Marsson in the recognition of d'Orbigny's genus.

1850. Genus Desmepora, Lonsdale, Dixon's 'Geol. Sussex,' p. 281.

64. Desmepora semicylindrica (= Idmonea semicylindrica, Römer), 'Geol. Sus.,' p. 281, pl. 18a, fig. 6.

There are slight variations in the size of fasciculæ in young and old examples of this abundant species. *Idmonea semicylindrica*, Röm., d'Orbigny regarded as a *Truncatula* ('Terr. Crét.,' p. 1054).

In Mr. Gamble's collection of Chatham Polyzoa there is a very beautiful example of this species, silicified and nearly transparent, which shows the inter-zoœcial and reverse reticulation and all the other characters of the species in the most perfect manner.

1852. Genus Semicytis, d'Orb. (*Osculipora* (pars), d'Orb., 1847), 'Terr. Crét.,' p. 1048.

65. Semicytis rugosa, d'Orb. = *Osculipora rugosa*, d'Orb., *op. c.*, p. 1049, pl. 795, figs. 1–7.

D'Orbigny gives the following localities where this species has been discovered:—Fécamp (d'Orb.); Folkestone (d'Orb.); Carancy (Defrance); and I now add Chatham, where it is somewhat rare.

66. Semicytis sp. (Francqana ?, 'Terr. Crét.,' p. 1052, pl. 794, fig. 14).

Of this citation I am rather doubtful. I have only seen the basal part of a zoarium, which resembles the basal part of d'Orbigny's figure.

1850. Genus Homœosolen, Lonsd., Dixon's 'Geol. Sussex,' p. 307.

It is very certain that some of the species characterised by d'Orbigny belong to the genus *Homœosolen*, as defined by Lonsdale. The three species of *Truncatula* of Hagenow, *T. filex*, *T. truncata*, and *T. repens*, are relegated by Marsson ('Bryoz. Weiss. Schreib. Rügen,' p. 37) to the genus *Osculipora*, d'Orbigny, under which name two of Hagenow's species are placed by him, as *O. truncata* = *Retepora truncata*, Goldf., and *O. repens*

= *Truncatula repens*, Hag. A third species of *Osculipora* (*O. Royana*, d'Orb., pl. 800 (*bis*), figs. 1–4) is recorded by d'Orbigny; but I have not seen the plate referred to, as it does not exist in my copy, and, so far as I am aware, in no other copy known to me. Neither *Osculipora*, d'Orb., nor *Truncatula*, Hag., can in any sense be regarded as the same as *Homœosolen*, Lonsd. The date of *Homœosolen*, Lonsd., 1850, and *Truncatula*, Hag., 1851, is sufficient apology for the restoration of the genus, which was fully described by Lonsdale. As, however, d'Orbigny's names are occasionally quoted by authors, I give full references to the Atlas of plates, for the purpose of showing the rich variety of forms belonging to this or allied species found in the Chatham Chalk:—[1]

67. Homœosolen ramulosus (Mantell), Lonsd., 'Geol. Sussex,' p. 307, pl. 18B, fig. 3 (typica).
68. ,, ,, variety, pl. 18B, figs. 4, 5.
69. ,, ,, forma (*Truncatula*) *aculeata*, d'Orb., pl. 796, figs. 1–5.
70. ,, ,, forma (*Truncatula*) *alternata*, d'Orb., pl. 797, figs. 1–4.
71. ,, ,, forma (*Truncatula*) *carinata*, d'Orb., pl. 797, figs. 7 and 12.

One of the localities (British) given by d'Orbigny for *T. carinata* is Folkestone ('Terr. Crét.,' p. 1050).

1851. Genus Truncatula, Hag., 'Bryoz. Maestricht. Kreid.,' p. 34.

The following are sufficiently distinct at Chatham to merit recognition:—

72. Truncatula subpinnata, d'Orb., 'Terr. Crét.,' p. 1055, pl. 796, figs. 6–9.
73. ,, tetragona, Mich. (= *T. gracilis*, d'Orb., *l. c.*, p. 1056, pl. 796, figs. 10–14; *l. c.*, p. 1059, pl. 798, fig. I.).

1821. Genus Apsendesia, Lamx.[2]

Under this genus Dr. Pergens places as synonyms the following genera:—*Radiofascigera*, *Unitubigera*, *Radiotubigera*, *Discotubigera*, *Actinopora*, and *Multitubigera*, all d'Orbigny's. Species belonging to this genus are not abundant in the Chatham Chalk.

74. Apsendesia papyracea (Unitubigera), d'Orb., 'Terr. Crét.,' p. 761, pl. 643, figs. 12, 14.
75. ,, organizans (Lichenopora), *id.*, d'Orb., pl. 646, figs. 9–13; *Radiotubigera*, *l. c.*, p. 757.
76. ,, regularis, d'Orb., *l. c.*, p. 763, pl. 763, figs. 7–9.

1823. Genus Lichenopora, Defrance.

77. Lichenopora (Bicavea) urnula, d'Orb., *l. c.*, p. 956, pl. 776, figs. 1, 2.
78. ,, sp.

I have found fragments of other forms of Lichenopora, but not sufficiently distinct for identification.

[1] There is also in Mr. Gamble's collection a pseudomorph in flint of *Homœosolen ramulosus*, Lonsd.

[2] See Dr. Pergens, *Revis. des Bryoz.*, p. 381.

1852. Genus SEMICEA, d'Orb., 'Terr. Crét.,' p. 1007.

79. Semicea lamellosa, d'Orb., *l. c.*, p. 1008, pl. 787, figs. 17–20.

1852. Genus REPTOMULTICAVA, d'Orb. = *Ceriopora* (pars), Goldf.; 'Terr. Crét.,' p. 1032.

80. Reptomulticava mamillata, d'Orb., *l. c.*, p. 1040, pl. 794, fig. 1. A young example.

81. Reptomulticava mamilla, d'Orb., *l. c.*, p. 1041, pl. 793, figs. 3, 4. Examples of this species are very small.

1826. Genus CERIOPORA, Goldfuss, 'Petrifacta.'

82. Ceriopora micropora ? Goldf., 'Petrif.,' p. 33, pl. 10, fig. 4.
83. „ (Semimulticava) (? tuberculata), d'Orb., pl. 648, fig. 4.
84. „ sp. (spongites?), Goldf., 'Petrifacta,' p. 35, pl. 10, fig. 14.

Sub-order CHEILOSTOMATA.

The classification of Cheilostomatous Polyzoa has undergone many changes during the last twelve years—or the period embraced since the publication of the first of my various reports on Fossil Polyzoa—and much really good work on the grouping has been done by specialists. It would be impossible in a brief notice like the present one to indicate the full meaning of these changes. By the old investigators zoarial and zoœcial characters were studied consecutively, but the diagnosis of a species was more dependent on zoarial than on zoœcial characters. In the Cretaceous Polyzoan fauna, as depicted by d'Orbigny in his really great work, we have, we must admit, a peculiar arrangement of grouping, based on a variety of zoarial growths. Thus, one species having different habits or modes of attachment will have a variety of specific and even generic names. This cumbrous method of dealing with the Polyzoan fauna, however, when once mastered, is not such a difficult task as one at first sight would imagine, as the figures of the species help us to understand any doubtful reference or diagnosis in the text. It is not, however, the classification of the future; and, though I have to a large extent followed d'Orbigny in his estimate of species, I have done so after reference to the newer work and suggestions of later authors. Were this a monograph of Cretaceous Polyzoa such a proceeding would be justly regarded as an offence, or at the least as disrespectful to other workers; but, as this is a report only on British Cretaceous Polyzoa, the course I have adopted may be ungrudgingly allowed, especially as full references are given to the text and atlas of d'Orbigny.

In my last report[1] I quoted from Phillips' 'Manual of Geology' (1885) Mr. Etheridge's estimate of the Upper-Cretaceous Polyzoan fauna, which he put down at 61 species. In the present report from one horizon of the Upper Chalk alone I have catalogued 125 really good species and varieties; and in all probability this may be considerably increased when all the Polyzoan fauna is as carefully examined as the Chatham Chalk has been by myself and Mr. Gamble. The general list, however, from all the zones of the Chalk, as given in the zonal divisions at the end of the report, has been nearly trebled.

[1] *Brit. Assoc. Rep.*, 1890, p. 378.

1850. Genus Vincularia, d'Orb., 'Terr. Crét.' (Not Defrance.)

This is by no means a satisfactory genus to deal with in the fossil state, or at least with those species which are found in the British Chalk. In a former report (1884[1]), on pp. 106–110, under the family term Cellaridæ, Hincks, I have already discussed the probable relationship of Vincularia species. In Mr. Waters' various papers species of Vincularia are relegated to either Membranipora or Micropora; but I note that in Miss E. C. Jelly's Synonymic Catalogue three of d'Orbigny's recent species are retained under the genus Vincularia (p. 271). In their joint paper ('Bryoz. de Faxe'[2]) Messrs. Pergens and Meunier retain the generic term Vincularia for species found in the débris of the Faxoe limestone of Denmark, and Dr. Marsson in his Rügen monograph also adopts this genus. In all probability in future classifications the genus will be disallowed, but no useful purpose would be served, so far as I can judge, in wholly suppressing the generic term in the present report on the Polyzoa found in the British Chalk. For the present, therefore, I retain the genus Vincularia for all those forms which are closely related to, or characteristically identical with, French 'Bryozoan' forms as described in the text and figured in the atlas of d'Orbigny.

85. Vincularia (Cellaria) cactiformis, d'Orb., 'Terr. Crét.,' p. 29, pl. 651, figs. 1–4.
86. ,, ,, inæqualis, d'Orb., *l. c.*, p. 30, pl. 651, figs. 5–8.
87. ,, cretacea, d'Orb., *l. c.*, p. 63, pl. 600, figs. 17–19.
88. ,, regularis, d'Orb., *l. c.*, p. 64, pl. 601, figs. 1–3.
89. ,, undata, d'Orb., *l. c.*, p. 75, pl. 656 (fig. 11 only).
90. ,, Gaudryana, d'Orb., *l. c.*, p. 193, pl. 682, figs. 1–3.
91. ,, areolata, Hag., 'Bryoz. der Maest. Kreideb.,' p. 60, pl. 6, fig. 12.

1834. Genus Membranipora, Blainville ('Terr. Crét.,' p. 539).

Generic character.—Zoarium encrusting or with an erect habit of growth. Zoœcia irregularly disposed, occasionally in linear series. Margins raised, front depressed, wholly or in part membranous.

92. Membranipora granulosa, d'Orb. (Flustrellaria), 'Terr. Crét.,' p. 523, pl. 725, fig. 2.
93. ,, confusa, d'Orb. (Flustrellaria), *l. c.*, p. 524, pl. 725, figs. 9–12.
94. ,, irregularis? d'Orb. (Flustrina), *l. c.*, p. 305, pl. 702, figs. 14–16.
95. ,, marginata, d'Orb. (Semiflustrina), *l. c.*, p. 579, pl. 733, figs. 5–8.
96. ,, monilifera, d'Orb. (Semiflustrina), *l. c.*, p. 577, pl. 732, figs. 6–9.
97. ,, pulchella, d'Orb., var. granulosa, new var. See 'Terr. Crét.,' pl. 701, figs. 7–9 (Flustrina). In all probability d'Orbigny's figures are drawn from a worn example of the species, whereas the British examples derived from the Chatham Chalk are beautifully granulated on the marginal walls.

[1] Fifth Report on Fossil Polyzoa.
[2] *Ann. de la Soc. Roy. Malacol. de Belgique*, 1886, tome xxi.

98. Membranipora argus, d'Orb. (Biflustra), *l. c.*, p. 253, pl. 689, figs. 1–4.
99. „ argus *forma* pulchella, d'Orb. (Biflustra), *l. c.*, p. 256, pl. 690, figs. 1–3.
100. „ pygmæa? d'Orb. (Biflustra), *l. c.*, p. 252, pl. 688, figs. 16–18.
101. „ dispersa, Hag. (Marsson, 'Die Bryoz. der Weiss. Kreideb.,' pl. v., fig. 8
=*Crisia Johnstoniana*, Mantell's 'Medals,' vol. i., p. 284, woodcut 64, fig. 3.

1848. Genus MICROPORA, Gray

=Membranipora, Busk (pars), 'Brit. Mus. Cat.' Multescharalina, d'Orb. Semieschara, d'Orb., and Reptescharellina, d'Orb. (pars). See Miss Jelly's 'Synon. Catalogue Marine Bryozoa.'

Zoarium encrusting. *Zoœcia* with prominent raised margins, front depressed, wholly calcareous. Orifices semicircular, or suborbicular, enclosed by a calcareous border. Hincks, 'Brit. Mar. Polyz.,' p. 173.

102. Micropora (Marginaria) Roemeri, Lonsd., 'Geol. Sussex,' pl. 18B, fig. 7, &c.
103. „ „ Var. *a*, with short avicularia.
104. „ „ Var. *b*, with long avicularia.
105. „ ? (Reptoporina?) intricata, Lonsd., 'Geol. Sus.,' p. 316, pl. 18B, figs. 8 to 8*b*.
=Escharina? micropora, d'Orb., 'Terr. Crét.,' pl. 605, figs. 5–7.
106. „ (Reptescharellina) oceana, d'Orb., 'Terr. Crét.,' pl. 605, figs. 14, 15.
107. Mucronella? (Cellepora and Escharina) simplex, d'Orb., 'Terr. Crét.,' p. 407, pl. 605, figs. 10, 11.

1848. Genus CRIBRILINA, Gray. (Reptescharella, d'Orbigny.)

Zoarium encrusting. *Zoœcia* contiguous, having the front more or less occupied by transverse or radiating punctured furrows. Orifice semicircular or sub-orbicular. (Hincks, 'Brit. Mar. Polyz.,' p. 184.)

108. Cribrilina fragilis, d'Orb. (Semieschariporа), 'Terr. Crét.,' pl. 717, fig. 9.

The British examples are closely allied to the *C. radiata*, Moll.; and the *C. fragilis*, d'Orb., may be only one of the many synonyms of this world-wide species.

109. Cribrilina linearis, sp. n.

In habit the nearest apparent ally of this species is the *Hippothoida brevis*, Reuss, 'Der Bryoz. u. Foram. des unteren Pläners,' pl. 24, fig. 7, but Reuss' figure does not show any cribriline features, and d'Orbigny does not give a figure of any linear examples of Cretaceous *Reptescharella*.

110. Cribrilina nitidiformis, sp. n.

This species is closely allied to the very variable *Membraniporella nitida*, Johnst.

1840. Genus Melicertites, Roemer.

Division C. Melicertitina, Pergens.[1]

In my last report on Cretaceous Polyzoa I accepted the divisions formulated by Dr. Marsson and Dr. Pergens as the latest attempt—by no means satisfactory—to classify Cretaceous Polyzoa. The *Elea* and *Melicertitina* groups have always been very difficult to deal with, especially the Upper-Cretaceous forms, as the 'closure' cells in the zoarium closely resemble the 'closure' cells of the Carboniferous *Polypora tuberculata*. Until quite recently it has been customary to place *Polypora* species amongst the Cyclostomata, but their true position must be left for the present. Since writing my last report I have had ample opportunity to study Cretaceous examples of *Melicertites*, which, though very abundant as individuals in the Chatham Chalk, are by no means abundant as species. I am now quite prepared to agree with Mr. A. W. Waters in his estimate of the genus. In a recent paper[2] that author has shown that the true Cheilostomatous characters, such as Avicularia, found in Cretaceous species, are sufficiently indicative as to their natural location as regards grouping. For the present, however, I can only give a record of the species already met with.

111. Melicertites Dollfussi, Perg., 'Revis. des Bryoz.,' p. 395, fig. 4.
112. „ semiclausa, Mich. (*Id.*, *l. c.*, p. 394).
113. „ semiclausa, forma Lorieri, d'Orb., 'Terr. Crét.,' pl. 601, figs. 18, 20.
114. „ propinqua (Nodelea), Mars., 'Rügen,' pl. 5, fig. 1.
115. „ propinqua, Mars.; or variety.
116. „ ? Near *Claviclausa globulosa*, d'Orb., 'Terr. Crét.,' pl. 765, fig. 15.

There is still another very doubtful genus, as regards proper location, which for the present I place here for convenience only.

1887. Genus Epidictyon, Marsson.

1850=Siphoniotyphlus, Lonsdale, 'Geol. Sus.,' p. 341.
1874. Lanceopora, Reuss, 'Pläners,' 1874, p. 130.

117. Epidictyon tenue, Hag. (1840), according to Marsson, 'Die Bryoz., &c., Rügen,' p. 17.

1801. Genus Eschara, Lam. (see d'Orb., 'Terr. Crét.,' pp. 96–104, for history of the genus).

The genus *Eschara* holds an important place in the classification of d'Orbigny and other Continental writers on Polyzoa, but, Mr. Hincks and Mr. Waters, in dealing with recent and fossil species, break up the group considerably. It is certainly an unmanageable group whenever reliance is placed upon the bilaminate character for diagnostic purposes. Yet the genus, as understood and worked by d'Orbigny and others, is a most interesting one, and so far as I am aware it reached its climax in the Cretaceous epoch. D'Orbigny describes and illustrates 80 species as belonging to the Chalk of France. Marsson describes several species as

[1] See Report on Fossil Polyzoa, *Brit. Assoc. Rep.*, 1890, p. 380.
[2] *Ann. Mag. Nat. Hist.*, S. 6, vol. viii., pp. 48–53.

found in the Rügen Chalk, and Hagenow describes and illustrates several very beautiful forms which are found in the Maestricht beds. Although I place the following species under *Eschara*, it must not be supposed that I disagree with modern methods of investigation. In all probability a rearrangement will take place in the grouping of species of this genus.

118. Eschara cleon, d'Orb., 'Terr. Crét.,' *l. c.*, p. 147, pl. 671, figs. 8–11. Typica.
119. „ cleon (?), or well-marked variety.

Large frondescent variety with *avicularia*. D'Orbigny's fig. 8 represents a small branching form, apparently without *avicularia*. The frondescent variety has the same form of cell and cell-area.

120. Eschara sexangularis (?), Goldf., Hag., 'Maestricht,' p. 81, pl. 10, figs. 3, 4, 5.

The shape of the cell is similar to figs. 4 and 5, but the avicularian cell is different. Rare in Chatham Chalk.

121. Eschara claudia d'Orb. (or near), 'Terr. Crét.,' p. 146, pls. 671, 675.
122. „ cybele, d'Orb. (or near), 'Terr. Crét.,' pl. 674, figs. 4–6.
123. „ danæ, d'Orb., 'Terr. Crét.,' pl. 675, figs. 7–13.

1816. Genus Lunulites, Lamarck.

124. Lunulites cretaceus, Defr., d'Orb., 'Terr. Crét.,' p. 349, pl. 704, fig. 2
(=L. urceolatus, Woodward, 'Geol. Norf.,' pl. 4, fig. 8, =L. radiatus, Mant., 'Medals,' pp. 256 and 290, Morris.)

1846. Genus Stichopora, Hag. (see d'Orb., 'Terr. Crét.,' p. 360).

125. Stichopora clypeata, Hag., 'Bryoz. Maestr.,' p. 100, pl. 12, fig. 14 =S. clypeata, d'Orb., 'Terr. Crét.,' p. 360, pl. 707, figs. 5–9.

The Chatham example is slightly broken on the edges, and it measures 7 mm. in diam. against the 9 mm. of d'Orbigny's example.

V. Polyzoa, Upper Chalk; Gravesend.

In Mr. W. Whitaker's 'Geology of London and of Part of the Thames Valley' (vol. i., pp. 83–85, 1889) will be found a list of fossils from the following localities:—(1) Lewisham, (2) Charlton and Woolwich, (3) Gravesend and Northfleet, and (4) Grays and Purfleet (Essex). The list was compiled by Mr. Jukes-Browne, from the catalogue of the collection in the Jermyn Street Museum, from Dr. Lavis' paper,[1] from a list of the late Mr. Wetherell's collection, taken by Mr. Whitaker—supplemented by references from the monographs of the Palæontographical Society and from specimens in the collections of Mr. Jukes-Browne and of Mr. W. Whitaker. Only two species of Polyzoa are mentioned in the list, but in a MS. note Mr. Whitaker gave me a list—probably compiled

[1] *Proc. Geol. Assoc.*, vol. iv., No. 9, pp. 528–530.

from Morris' 'Catalogue of British Fossils'—of six additional species of Polyzoa, which had been previously recorded from the No. 3 locality given above. Until 1889 these were all the Cretaceous Polyzoa from Gravesend known to the respective authors.

In June 1890, with the other material already referred to,[1] I received from Professor T. Rupert Jones, F.R.S., a small packet labelled 'Gravesend.' This proved to be pickings, or refuse material, which remained after Mr. Jones had selected the Foraminifera and Entomostraca. In the packet I found a number of minute fragments of well-preserved Polyzoan remains—besides other organisms—and the following list is the result of my labours on this small collection. I have included in the list the names only of species of whose identity I felt assured; but there were other fragments which would help me to add to the list if better material could be forthcoming. I do hope, therefore, that local students will search for and record their discoveries in this, as well as in other districts where the Upper Chalk rocks are exposed. Examples of all the species recorded below are in my own cabinet. Professor Morris' list is given separately, because, as yet, I have not been able to identify any of the species named.

Sub-order Cyclostomata, Busk.

Idmonea unipora, d'Orb., 'Terr. Crét.,' p. 737, pl. 613.
,, subgracilis, d'Orb., 'Terr. Crét.,' p. 738, pl. 614.
Filisparsa (pulchella?), Marsson, 'Der Bryoz. der Weiss. Kreidebil.,' pl. 3, fig. 7.
Entalophora proboscidea (Edw., Perg., 'Revis. des Bryoz.,' p. 359).
,, forma raripora, d'Orb., 'Terr. Crét.,' p. 787, pl. 621.
,, ,, filiformis, d'Orb., *l. c.*, p. 791, pl. 622.
Heteropora (*Sparsicavea*) Francqana, d'Orb., *l. c.*, p. 951, pl. 775.
Apsendesia (*Lichenopora*) organizans, d'Orb., *l. c.*, p. 757, pl. 646, figs. 9–13.
Homœosolen ramulosus, Lonsd., 'Geol. Sus.,' p. 307, pl. 18B, figs. 3–5.
Reptomulticava mamilla, d'Orb., 'Terr. Crét.,' p. 1041, pl. 793.
Multicrescis sp. (Heteropora, Perg., 'Revis. des Bryoz.,' p. 373).

Sub-order Cheilostomata, Busk.

Planicellaria oculata, d'Orb. (one segment only), 'Terr. Crét.,' p. 37, pl. 653.
Vincularia regularis, d'Orb. (typica), *l. c.*, p. 64, pl. 601, figs. 1–3.
,, forma Santonensis, d'Orb., *l. c.*, p. 73, pl. 656, fig. 2.
,, ,, perangusta? d'Orb., *l. c.*, p. 83, pl. 658, fig. 11 (or near).
Membranipora sp.
Micropora Roemeri, Lonsd., 'Geol. Sus.,' pl. 18B, fig. 7.
Melicertites sp. (near M. Francqana, d'Orb., pl. 737, fig. 16).
Eschara sp.

The following are recorded by Professor Morris from Gravesend ('Cat. British Fossils,' edition 1854):—

*Diastopora gracilis, M. Ed., 'Ann. Sc. Nat.,' 1838, p. 229, pl. 14, fig. 3.

[1] *Brit. Assoc. Rep.* (1890) on Cretaceous Polyzoa, p. 390.

*Idmonea ? truncata, Blain., 'Man. d. Act.,' p. 420=*Millepora*, Woodward.
*Pustulopora madreporacea, Goldf., 'Petrifac.,' p. 35, pl. 10, fig. 12.
* „ pustulosa, Lonsd., Dix., 'Geol. Sus.,' pl. 18A, fig. 8 (Northfleet).
*Actinopora (Tubulipora) Brongniartii, M. Ed., 'Ann. Sc. Nat.,' pl. 14, fig. 1.
*Eschara cancellata, Goldf., 'Petrifac.,' p. 34, pl. 8, fig 13.
* „ disticha, Goldf., *l. c.*, p. 25, pl. 30, fig. 8.
* „ pyriformis, Goldf., *l. c.*, p. 24, pl. 8, fig. 10.

VI. The Salisbury Polyzoa.

The only record that I have of Polyzoa from Wiltshire or Hampshire is that given by Professor Morris in his 'Catalogue of British Fossils.' (The asterisks on the left-hand side indicate that I have no examples of the species catalogued.)

Alecto (Stomatopora) gracilis, M. Ed., 'Ann. Sc. Nat.,' t. 16, fig. 2, Wiltshire.
Petalopora pulchella, Lonsd., Dix., 'Geol. Sus.,' pl. 18A, fig. 7, Wiltshire.
Lunulites cretaceus, Defr., d'Orb., 'Terr. Crét.,' pl. 704, fig. 2, Wiltshire.
*Idmonea cretacea, M. Ed., 'Ann. Sc. Nat.,' t. 12, fig. 5, Hampshire.
*Eschara Lonsdalii „ „ „ 2 ser., t. 12, fig. 18, Portsmouth, Hampshire.
„ sexangularis, Goldf., 'Petrifac.,' p. 24, t. 8, fig. 12, Portsmouth, Hampshire.

In 1891 I received from Dr. Blackmore, of Salisbury, a very beautiful series of Polyzoa, which had been collected from the different zones of the Upper Chalk in the neighbourhood of Salisbury. The zonal successions as characterised by Mr. Westlake I have already adopted in a previous part (p. 4) of the present report; but a few other remarks may be advantageously quoted from the same paper [1] by way of explanation. 'The Upper Chalk is a very pure calcareous sediment. The time which elapsed during its deposit was sufficient to allow of a variation in the forms of the shellfish and the replacement of one by another. We can trace this in the Upper Chalk of our own valley, from its lowest part (with *Micraster cor-testudinarium*) in the pit east of Clearbury, to the highest (with *Belemnitella mucronata*), which appears in the pits of Redlynch, Searchfield, Breamore, Outwich, Whitsbury, Brookheath, West Park, and Damerham.' In sending me the Polyzoa, Dr. Blackmore gave in his letters very full notes respecting the various zones from whence the forms were derived. The *Belemnitella quadrata* zone seems to have yielded the greater number of species, probably on account of its being so largely used in the neighbourhood of Salisbury for the purpose of manufacturing whiting. The localities specialised by Dr. Blackmore are East Harnham and Whaddon. Sections of the Chalk have been exposed in the higher zone, with *Belemnitella mucronata*, at Clarendon and Short End. This zone, Dr. Blackmore remarks, corresponds with the Norwich beds, excepting those at Tormingham, which are probably

[1] 'Outlines of the Geology of Fordingbridge, &c.,' from *Mitchell's Fordingbridge Almanack and Directory*, 1889, p. 7.

Danian. The zone of *Marsupites testudinarius* has yielded a few forms, chiefly from the locality of Highfield, and the zone of *Micraster cor-anguinum* has also yielded several very beautiful species, some of which are unique. The localities are Witherington, Horsebridge, and Quidhampton.

Unfortunately the great bulk of the Salisbury Polyzoa were unsuited for microscopical examination on account of their size. Since these were examined and returned to Dr. Blackmore with a temporary list of species, the mass of Chatham Polyzoa which I was able to mount as slides have been most carefully studied for the purpose of identification, and in some few cases I have altered the name given in the temporary list. It is right that I should make this remark, because it is the intention of Dr. Blackmore, I believe, to place the series of Polyzoa referred to, when properly arranged, in the Salisbury and South-Wilts Museum. In the present list the series is arranged consecutively. In the columns the zones where the species were found are indicated by the typical letters already referred to, and on the extreme right the name of the locality as given by Dr. Blackmore. I have only the broken fragments which became detached in the passage of the Salisbury species, and a few forms presented to me by Dr. Blackmore—Lunulites, &c.—so that the present list is compiled from careful notes and drawings of the species made during the time that the collection was in my hands. From other localities I have similar examples of the species indicated in the list, and I have only placed the usual asterisk (*) against those forms that I have no duplicate of. My identification of these may probably be erroneous, so that I will advise Dr. Blackmore and other collectors in Salisbury and its neighbourhood to verify the accuracy in my present list of the specific names so indicated. I had Polyzoa from four zones only, Zone E not being represented.

(The small figures on the right-hand side refer to the habitats on which the species were found. See list at the end of this section.)

—	Bel. mu. A.	Bel. quad. B.	Marsup-cor. C.	Micras. cor-ang. D.	—
Sub-order CYCLOSTOMATA.					
Genus Stomatopora, Bronn.					
Stomatopora granulata, var. gigantea, Perg.		*			Whaddon.
,, gracilis, Edw. . .		*		*	E. Harnham and Quidhampton.
,, Dixoni, Vine, and var. .			*	*	Highly, Highfield(3) and Quidhampton.
,, longiscata, d'Orb. .		*			E. Harnham.
,, pedicellata, Marsson .				*	Quidhampton (3).
Genus Proboscina, d'Orb.					
*Proboscina Bohemica, var. delicatula, Vine		*			E. Harnham (2).
* ,, flexuosa, Vine . .		*		*	E. Harnham and Quidhampton.
,, gigantopora, Vine		*			E. Harnham.

—	Bel. Mu.	Bel. quad.	Marsup.-cor.	Micras. cor-ang.	—
	A.	B.	C.	D.	
Sub-order CYCLOSTOMATA—*cont.*					
Proboscina marginata, d'Orb.				*	Quidhampton (3).
,, ? littoralis, d'Orb.			*		Highfield.
Genus Diastopora (Berenicea, Lamx.)					
Diastopora grandis, d'Orb.				*	Quidhampton (3).
,, papillosa, Rss.				*	,,
,, ,, forma echinata, d'Orb.				*	,,
,, congesta, Rss., d'Orb.				*	,,
Genus Idmonea (Crisina, d'Orb.)					
Idmonea triangularis, d'Orb.		*			E. Harnham and W. Harnham.
Genus Reptotubigera, d'Orb.					
*Reptotubigera serpens, d'Orb.				*	Quidhampton (3).
Genus Clinopora, Marsson					
Clinopora costulata, Marsson					?
Genus Entalophora, Lamx.					
Entalophora proboscidea, Edw.		*			E. Harnham.
* ,, pustulosa, Goldf.		*			,,
Genus Heteropora, Pergens					
Heteropora, sp. or var. new		*			,,
,, (Clausa) carantina, d'Orb.		*			,,
Genus Cavarinella, Marsson.					
Cavarinella ramosa, Hag. sp.		*			,,
Genus Desmepora, Lonsd.					
Desmepora semicylindrica, Lonsd.		*			,,
Genus Homœosolen, Lonsd.					
Homœosolen ramulosus, Lonsd.		*			,,
,, ,, forma alternata, d'Orb.	*	*			Clarendon and E. Harnham.
,, ,, forma carinata, d'Orb.	*				Heybrook and Clarendon.
Genus Umbrellina, Rss.					
Umbrellina (Lichenopora) paucipora, Vine		*			E. Harnham.
Genus Unicavea, d'Orb.					
Unicavea collis, d'Orb.				*	Horsbridge (5).
Genus Apsendesia, Lamx.					
Apsendesia Gaudryana, d'Orb.	*				Clarendon.
Sub-order CHEILOSTOMATA.					
Genus Cellaria, d'Orb.					
Cellaria cactiformis, d'Orb.	*				,,
Genus Vincularia, d'Orb.					
Vincularia Francqana, d'Orb.	*				,,
,, excavata, d'Orb.		*			E. Harnham.
,, simplex, d'Orb.	*				Clarendon.
,, regularis, d'Orb.	*				,,
Genus Membranipora, Blainville.					
Membranipora (Hippothoa) dispersa, Mars.		*		*	E. Harnham (9).

—	Bel. mu. A.	Bel. quad. B.	Marsup.-cor. C.	Micras. cor-ang. D.	—
Sub-order CHEILOSTOMATA—*cont.*					
Membranipora tuberosa, Novák (var.?)		*			E. Harnham and Whaddon.
„ elliptica, Hag. sp.		*			E. Harnham.
* „ clathrata, Rss. (unique)		*			E. Harnham.
„ irregularis, d'Orb.				*	Quidhampton (3).
„ (Biflustra), pauperata, d'Orb.		*			E. Harnham.
„ ? (Flustrina) irregularis, d'Orb.					
Genus Micropora, Gray?					
Micropora hippocrepis, Goldf.					
„ rimosa (non Eschara), Mars.		*			„
„ Delarueana (non Eschara), d'Orb.				*	Witherington (3).
„ (Marginaria) Roemeri, Lonsd.				*	„
„ confluens? Reuss					
Genus Cribrilina, Hincks.					
*Cribrilina (Semieschariporα) brevis? d'Orb. pl. 718			*		Highfield.
„ (Semieschara), flabellata, d'Orb.	*				Clarendon.
„ (Semieschariporα) fragilis? d'Orb.					Aldenborough.
„ (Disteginopora) horrida, d'Orb.				*	Witherington.
„ (Reptescharella) pygmæa, d'Orb.		*			E. Harnham.
Genus Porina, d'Orb.					
*Porina pustulosa?, Marsson		*			„
„ cincta?, Reuss		*			„ (9).
Genus Epidictyon, Marsson; Siphoniotyphlus, Lonsd.					
Epidictyon tenue, Hag. = S. plumatus? Lonsd.	*				Clarendon.
Genus Melicertites, Röm.					
Melicertites semiclausa, d'Orb.			*		Highfield.
„ „ forma Lorrieri, d'Orb.			*		„
„ (Claviclausa) globulosa, d'Orb.					
Genus Eschara, d'Orb.					
Eschara Danæ, d'Orb.		*			E. Harnham.
„ Acis, d'Orb.		*			„
„ cypræa, d'Orb.		*			„
„ Delarueana, d'Orb		*			„
„ rimosa, Marsson		*			„
Genus Discoflustrellaria, d'Orb.					
* „ doma, d'Orb.		*			„
Genus Lunulites.					
Lunulites rosaceus, d'Orb.		*			„
„ cretaceus, Defranc.					

HABITATS. *Fossils on which the various species were found.*

1. Bourgueticrinus ellipticus, Mill.
2. Cardiaster pilula, Lam.
3. Micraster cor-anguinum, Leske.
4. Echinoconus, sp.
5. Rhynchonella octoplicata, Sow.
6. Ostrea vesicularis, Lam.
7. Inoceramus, sp.
8. Belemnitella mucronata, Sch.
9. „ quadrata, Defr.
10. Echinocorys vulgaris, Breyn = *Ananchytes ovatus*, Leske.

VII. POLYZOA, BERKSHIRE AND BUCKINGHAMSHIRE.

In Mr. W. Whitaker's 'Geology of London and Part of the Thames Valley,' vol. i., p. 76 (1889), will be found remarks on the fossil contents of the various pits in Berkshire visited by Mr. Rhodes. In the Twyford and Maidenhead districts Chalk was quarried in many places, and Mr. Rhodes collected fossils from such pits as were still in use. A list of fossils procured from these pits will be found at pp. 79 and 80, amongst which are several Polyzoa. The Chalk in all the pits—of which localities are given—is characterised by certain fossils, which are either rare or absent in the beds below. These are :—

Bourgueticrinus (? *ellipticus*), Miller.
Cidaris peronata, Forbes.
Micraster cor-anguinum, Leske.
Ostrea acutirostris, Nils.
Pecten nitidus, Mant., with many *Polyzoa* and *Serpulæ*.

There can be little doubt, says Mr. Rhodes, that this Chalk belongs to the zone of *Micraster cor-anguinum*, whilst that with the spongeous flint (Cookham Dean) may be referred to the zone of *Micraster cor-testudinarium* (p. 76).

In a pit quarried on the Buckingham side of the Thames is a layer of greyish gritty Chalk in blocky masses resembling Totternhoe stone, without flints, in which are *Belemnitella quadrata* and *Ostrea acutirostris;* and the presence of these fossils, with a comparative scarcity of flints, suggests a correlation of this Chalk with the Margate Chalk of the zone *Marsupites testudinarius* (p. 77).

The Polyzoa, partially and fully identified by Mr. Rhodes, are as follows:—

Diastopora, sp. Idmonea and Escharina sp., Littlewick.
Diastopora, sp. only, Bisham.
Entalophora and Membranipora, Pinkneys.
Proboscina angustata d'Orb., 'Terr. Crét.,' pl. 632, Marlow.
„ ramosa, d'Orb., 'Terr. Crét.,' pls. 632, 633, Marlow.
Entalophora cenomana, d'Orb., 'Terr. Crét.,' pl. 618, Waltham.
Semieschara arborea, d'Orb., 'Terr. Crét.,' pl. 710.

VIII. POLYZOA, HERTFORDSHIRE AND MIDDLESEX.

Several Chalk pits in the neighbourhood of Rickmansworth and Watford were examined by Mr. Rhodes, and with very satisfactory results as regards Polyzoa. In all probability the Chalk of these pits also is in

the junction of the *Micraster cor-anguinum* and *M. cor-testudinarium* zones. The Polyzoa, identified and otherwise, are as follows:—

Stomatopora ramea, Blainv., 'Man. d. Act.,' pl. 78, fig. 6, Harefield.
" sp., Rickmansworth.
Idmonea (crisina) subgracilis, d'Orb., 'Terr. Crét.,' p. 738, pl. 614, Watford.
Entalophora (Clavisparsa) clavata, 'Terr. Crét.,' p. 776, pl. 621, Watford.
" (Clausa ?) obliqua, d'Orb., *l. c.*, p. 896, pl. 623, Watford.
" proboscidea, forma raripora, d'Orb., *l. c.*, pls. 621 and 623, Watford.
Bicavea dilatata, d'Orb., 'Terr. Crét.,' p. 956, pl. 776, Watford.
Truncatula alternata, d'Orb., 'Terr. Crét.,' *l. c.*, pl. 797, Watford.
Domopora clavata (Ceriopora, *id.*, Goldf.), d'Orb., 'Terr. Crét.,' p. 988, Watford.
Actinopora (Apsendesia) diademoides, d'Orb., *l. c.*, p. 764, pl. 643, Harefield.

Besides the species identified at Watford are the following, indicated by generic names only:—

Stomatopora (Alecto), Diastopora, Vincularia, Membranipora, and Eschara, sp.

At Harefield, Rickmansworth, Bushey, Letchmore, and Colney Street, species (unnamed) of the following genera have been found, probably in the 'Flint Meal' from the hollows of flints:—

Alecto, *Diastopora*, *Defrancia*, *Cellepora*, and *Escharina*.

Of the undetermined species I cannot speak, not having as yet seen the material ('Geol. Lond. and Part of Thames Valley,' p. 80, vol. i.).

IX. Polyzoa, Charlton, near Woolwich.

I am not aware whether any record has been given of Polyzoa having been found in the Charlton Pit. In 1860 I was living at Woolwich for a short time, when I collected both Tertiary and Cretaceous fossils. Recently, while examining some of the larger forms, I found the following species of Polyzoa encrusting *M. cor-anguinum* and *Echinocorys vulgaris*, but they are by no means fine examples of colonial growths like those found on Gravesend or Chatham fossils:—

Stomatopora gracilis, Bronn.
" Dixoni, Vine.
Membranipora fragilis, d'Orb.
Micropora Roemeri, Lonsd.
Cribrilina sp. Too much worn for specific determination.

X. Polyzoa, Norfolk, Sussex, and Kent.

For this section of my labours there only remain now the Polyzoa of the Upper Chalk of Norfolk and of Suffolk to chronicle. This I must do on the authority of Professor Morris, as I have only a very few fossils on which I could rely for information. The Polyzoa in Sussex are evidently —judging by Lonsdale's labours, as described and illustrated in Dixon's

'Geol. of Sussex'—very abundant. On one fossil alone—*Micraster cor-anguinum*—from Sussex I have been able to identify eight species of Polyzoa belonging to the two sub-orders Cyclostomata and Cheilostomata.

(*a*) *Norfolk* (*Woodward's 'Geol. of Norfolk'*). *Morris' Catalogue.* Zone: Belemnitella mucronata.

Stomatopora gracilis, Woodw., 'Geol. Norf.,' pl. 4, fig. 16.
Diastopora gracilis, M. Ed., 'Ann. Sc. Nat.,' 1838, p. 229, pl. 14, fig. 3.
Ceriopora polymorpha, Goldf. (Millipora, Woodw.), 'Geol. Norf.,' pl. 4, fig. 13.
Discopora ? mamillata, Woodw., 'Geol. Norf.,' pl. 4, fig. 2.
,, ? radiata, Woodw., 'Geol. Norf.,' pl. 4, fig. 3.
*Flustra (?) quadrata, Woodw., 'Geol. Norf.,' pl. 1, fig. 3.
* ,, (?) retiformis, Woodw., 'Geol. Norf.,' pl. 4, fig. 6.
* ,, (?) tessellata, Woodw., 'Geol. Norf.,' pl. 4, fig. 4.
Lunulites urceolatus, Woodw., 'Geol. Norf.,' pl. 4, fig. 8 = L. cretaceus, d'Orb., pl. 704.

If I am right in my identification, the Millepora (truncata), Woodw., which Professor Morris identifies as *Retepora truncata* ?, Goldf., is really the *Truncatula truncata*, Hag. = *Osculipora truncata*, d'Orb. (1847). I have, however, a very peculiar species (*Reteporidea*, d'Orb.) from Norfolk, adherent to *Belemnitella mucronata*, but the form is too much silicified for specific distinction.

(*b*) *Sussex* (*S*) *and Kent* (*K*). *Morris' Catalogue.*

From these localities only those species are here indicated which I have not as yet identified in the present report.

Diastopora Sowerbii, Lonsd., Dixon's 'Geol. Sus.,' pl. 18A, fig. 2 (K, S).
Idmonea cretacea, M. Ed. = *Idmonea Dixoni*, Mant., p. 287 = Desmepora.
* ,, divaricata, d'Orb., 'Terr. Crét.,' pl. 631, figs. 9–11.
*Atagma papularium, Lonsd., 'Geol. Sus.,' pl. 18B, fig. 6 (S).

This species is probably represented in the Chatham Chalk as Heteropora papularia.

*Holostoma contingens, Lonsd., 'Geol. Sus.,' pl. 18A, fig. 10 (S, K).
*Actinopora Brongniarti, d'Orb. = Tubulipora Brongniarti, M. Ed.
* ,, pulchella, d'Orb., 'Terr. Crét.,' pl. 644, figs. 9–11 (Mackie, K).

XI. Polyzoa, Beachy Head, Sussex.

In 1882 I received from Miss E. C. Jelly a small parcel of Cretaceous Polyzoa derived from the cliffs of Beachy Head in Sussex. I have not the collection at hand to refer to, but as I gave particulars of these in a former report ('Brit. Assoc. Rep.,' 1883) it may be as well to correct the few inaccuracies which were unavoidable at the time I wrote.

Stomatopora Dixoni, sp. n. = *S. gracilis* (pars), Report, 1883.
Proboscina ramosa, Mich. = *S. ramosa*, Report, 1883.

Reticulipora obliqua, d'Orb. = Diastopora reticulata (new sp. ?), Report, 1883.
Micropora Roemeri, Lonsd.=Membranipora Roemeri, Report, 1883–4.

The other species given in the Report must be allowed to stand for the present.

It was my intention to give descriptions of the new species introduced into this Report, but as in all probability a monograph of the Cretaceous Polyzoa will be the outcome of my past and future investigations, it will be perhaps a better plan to reserve my descriptions until I can furnish figures of the same.

XII. Zonal Distribution of British Cretaceous Polyzoa.

(*a*) *Bibliographical References, &c.*

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2. Dr. Pergens: 'Revis. des Bryoz. du Crétacé, figurés par d'Orbigny,' 'Bull. de la Soc. Belge de Géol.,' t. iii., 1889.
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4. Dr. F. von Hagenow: 'Die Bryoz. der Maestricht. Kreideb.,' Cassel, 1851.
5. Dr. Mantell: 'Medals of Creation,' 1844 edition.
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9. „ 'Die Foram., Bryoz., und Ostrocoden des Pläners,' 1874.
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12. „ Notes on Cambridge Greensand Polyzoa, &c., 'Proc. Yorks. Geol. Polytech. Soc.,' vol. ix., 1886.
13. „ Further Notes on the Camb. Greensand Polyzoa, pl. 2, *Ibid.*, vol. xi., 1889.
14. „ Notes on sp. Entalophoræ, Lincolnshire, 'Ann. Mag. Nat. Hist.,' 1887.
15. „ Polyzoa of the Red Chalk of Hunstanton, 'Quart. Journ. Geol. Soc.,' vol. xlvi., 1890.
16. „ Notes on the Polyzoa, &c., of the Red Chalk, 'Proc. Yorks. Geol. Soc.,' vol. xi., 1890.
17. „ Report on Cretaceous Polyzoa, 'Brit. Assoc. Rep.,' 1890.
18. A. W. Waters: On Cheilostomatous Characters in Melicertites, &c., 'Ann. Mag. Nat. Hist.,' July 1891.
19. Catalogue (1878) of Museum Practical Geol.=Cretaceous division.
20. G. R. Vine: Notes on New or Little-Known Eocene Polyzoa, 'Proc. Yorks. Geol. Soc.,' vol. xii., 1892.
21. „ Additions to the Cretaceous Polyzoa Fauna, 'Proc. Yorks. Geol. Soc.,' vol. xii., 1892.

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk
	Sub-order CYCLOSTOMATA, Busk.						
	Stomatopora, Bronn, d'Orb. :						
1	„ gracilis, Edw. (Bibl.[1] **1**, p 843, pl. 758, figs. 17, 18)				*		*
2	„ var. delicatula, Vine (**16**, pl. 17, fig. 1)				*		
3	„ pedicellata, Marsson (**7**, pl. 1, fig. 1)						*
4	„ graciliformis, Vine (**13**, pl. 12, fig. 2)		*				
5	„ divaricata, Röm. (**16**, pl 17, fig. 6)				*		
6	„ rugulosa, Reuss (**8**, pl. 27, fig. 8) .				*		
7	„ linearis, d'Orb. (**16**, pl. 17, fig. 5) .				*		
8	„ „ var. Mortoni, Vine (**13**, pl. 12, fig. 1)		*				
9	„ Dixoni, Vine = *Alecto gracilis* Lonsd. (non Edwards) (**6**, pl. 18B, fig. 1)						*
10	„ longiscata, d'Orb. (**16**, pl. 17, fig. 4)				*		*?
11	„ ramea, Blainv. (**16**, pl. 17, fig. 2) .				?		*
12	„ granulata, Edw. (**16**, pl. 17, fig. 3)				*		
13	„ „ var. incrassata, d'Orb. (**15**, p. 465)				*		
14	„ „ var. gigantea, Perg. (**2**, p. 331)						*
15	„ „ var. reticulata, d'Orb. (**1**, pl. 630, figs. 1–4)	*					*
16	„ variabilis, Vine (**21**, pl. 6, figs. 1A, 1B)				*		
	Proboscina, d'Orb. = Stomatopora (pars) Pergens (**2**)						
17	„ angustata, d'Orb. (**15**, p. 467, pl. 19, fig. 1)		*		*		
18	„ rugosa ? d'Orb. (**15**, p. 468) . .		*		*		
19	„ irregularis, Vine (**15**, pl. 19, fig. 2) .				*		
20	„ uberrima, Vine (**15**, p. 469, pl. 19, fig. 3)				*		
21	„ gracilis, var. Reussi, Vine (**15**, pl. (19, fig. 4)				*		
22	„ subelegans, d'Orb. (**15**, p. 470) .	*			*		
23	„ Hunstantonensis, Vine (15, pl. 19, fig. 10)				*		
24	„ „ ampliata, Vine (**15**, pl. 19, fig. 11)				*		
25	„ Jessoni, Vine (**15**, pl. 19, fig. 12) .				*		
26	„ gigantopora, Vine (**15**, pl. 19, fig. 8)		*		*		
27	„ bohemica ? Novák (**15**, pl. 19, fig. 9)				*		
28	„ „ var. delicatula, Vine (present report)						*
29	„ Toucasiana, d'Orb. (**2**, pl. 11, fig. 8).				*		
30	„ dilatata, d'Orb. (**1**, pl. 632, & **16**, p. 377)				*		
31	„ „ var. cantabrigensis, Vine (**13**, p. 263)		*		*		

[1] Bibliography, *ante*.

Nos.	Genera and Species	Neocomian	Camb. Green-sand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk
	Sub-order CYCLOSTOMATA, Busk—*cont.*						
32	Proboscina ramosa, d'Orb = *S. Sarthacensis*, Perg. (**13**, p. 264)		*		*		
33	„ cornucopiæ, d'Orb. (**1**, p. 855, pls. 633, 634)	*?					*
34	„ „ var. eximia, Vine (present report)						*
35	„ marginata, d'Orb. (Sharpe, Morris, Cat.)	*					*
36	„ Wetherelli, Morris (**6**, pl. 18A, fig. 6)						*
37	„ elevata, d'Orb. (**2**, p. 333) (**1**, pl. 760, figs. 1–3)	*					*
38	„ flexuosa, Vine (present report) .						*
39	„ inornata, Vine (**21**, pl. 2, fig. 4) .				*		
	Reptotubigera d'Orb. (**1**, p. 751)						
40	„ serpens, d'Orb. (Salisbury) (**1**, pl. 751, fig. 5)						*
41	„ ramosa, d'Orb. (Chatham) (**1**, pl. 751, fig. 2)						*
42	„ „ var. (*a*) irregularis, Vine (present report).						*
43	„ „ var. (*b*) disciformis, Vine (present report).						*
44	„ elegans, sp n. (present report) .						*
	Tubulipora, Lam. (non Reptotubigera, d'Orb.)						
45	„ Chathamensis, sp. n. (present report)						?
46	„ „ var. ornata, var. n. (present report).						?
	Diastopora, Lam. (= Berenicea, d'Orb.)						
47	„ cretacea (?), Vine (**10** and **13**, p. 265)		*?				*
48	„ Hagenowi, Reuss (13, p. 266, pl. 12, fig 9).		*				
49	„ fœcunda, Vine (**12**, p 9, **13**, p. 266)		*		*		
50	„ (congesta stage) (**13**, p. 269) .		*				
51	„ congesta, d'Orb. (**1**, pl. 640, fig. 2 only).						*
52	„ Clementiana, d'Orb. (**13**, p. 269 and 21, Gault form).		*				
53	„ gracilis, d'Orb. = *B. polostoma*, Röm. (**17**, p. 287, Gault form).	*					
54	„ grandis, d'Orb. (**1**, pl. 639, fig. 4–8).						*
55	„ Sowerbii, Lonsd. (**6**, pl. 18A, figs. 2, 2A).					*	
56	„ megalopora, Vine (**12**, p. 10, pl. ii., fig. 9).		*				
57	„ papyracea, d'Orb. (**17**, p. 288). .	*					
58	„ ramulosa, Mich. (**17**, p. 283) . .	*					
59	„ tuberosa, Mich. (**17**, p. 283, **1**, pl. 629)	*					
60	„ Hunstantonensis, Vine (**15**, pl. 19, fig. 10).				*		
61	„ „ var. contracta ? Seely (**16**, p. 370).				*		
62	„ regularis, d'Orb. (**1**, pl. 636, fig. 10 only).				*		

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk
	Sub-order CYCLOSTOMATA, Busk—*cont.*						
63	Diastopora radians? Nóvak (15, p. 477) . .				* *		
64	„ papillosa, Reuss (15, p. 477) . .				* *		*
65	„ „ forma echinata, d'Orb. (2, p. 334, pl. xi., fig. 6).						*
66	„ Jessoni, Vine (15, pl. 19, fig. 12, p. 478).				*		
*67	„ tubulus, d'Orb. (Entalophora form, 1, pl. 641).					*	
68	„ littoralis, d'Orb. (1, p. 867, pl. 640, fig. 7, 8).						*
	Idmonea, Lam. (= Crisina (pars), d'Orb.)						
69	„ unipora, d'Orb. (1, pl. 613, fig. 1–10) (Filisparsa?).						*
70	„ subgracilis, d'Orb. (1, pl. 614, fig. 6–10) (Filisparsa?)						*
71	„ francorum, Perg. (2, p. 343, pl. 13, fig. 1).						*
72	„ pseudodisticha, Hag. (2, p. 348) .						*
73	„ var. (*a*), (present report) . .						* *
74	„ var. (*b*), „ . . .						* *
75	„ dorsata, Hag. (4, pl. 2, fig. 10) . .		*?				* *
76	„ cypris, d'Orb. var. (*a*), (1, pl. 749) .						* *
*77	„ divaricata, d'Orb. (Morris' Catalogue)						M.
*78	„ gradata, Defr. „ „ .						M.
*79	„ clathrata, Goldf. „ „ .					M.	
80	„ triangularis, d'Orb. (1, pl. 612 and 769)						*
81	„ carantina? d'Orb. (1, p. 734, pl. 748, figs. 1–5)						*
82	„ sp.						*
	Reticulipora, d'Orb. (1, p. 903; 2, p. 354).						
83	„ papyracea, d'Orb. (1, pls. 611 and 768).						*
84	„ obliqua, d'Orb. (1, pls. 610 and 768)						* *
85	„ complanata, Mars. (7, pl. 3, fig. 10)						*
	Hornera, Lam.						
86	„ carinata, Rss. (Bohm's Kreide, pl. 14, fig. 6).			*			
87	„ ramosa, d'Orb., Cretaceous sp. found in the London Clay, Fareham (20, p. 54)						
	Filisparsa, d'Orb.						
88	„ ornata, Rss. (17, p. 292) . . .		*	*			
89	„ pulchella (?) Mars. (7, pl. iii. fig. 7)					*	
	Entalophora, Lam. (2, p. 357).						
90	„ proboscidea, Edw. (2, p. 359 (typica)						*
91	„ forma raripora, d'Orb. (1, pl. 621)		*				* *
92	„ „ Iconensis, d'Orb. (1, pl. 616)						* *
93	„ „ filiformis, d'Orb. (1, pl. 622)						* *
94	„ „ rustica, Hag. (2, p. 360) .						* *
95	„ „ elegans, Vine (11, pl. 1, fig. 1)		*				
96	„ geminata, Hag. (4, pl. 1, fig. 11) .						*
97	„ clava, d'Orb. (1, pl. 620, figs. 4–5) .						* *
98	„ madreporacea, Goldf., Petrifac. pl. 10, fig. 12.)						*

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk
	Sub-order CYCLOSTOMATA, Busk—*cont.*						
99	Entalophora madreporacea, forma inconstans, d'Orb. (1, pl. 754)						*
100	„ Cenomana, d'Orb. (1, pl. 618, figs. 11–15).	*				*	W[1]
101	„ costata ? d'Orb. (1, pl. 621–17, p. 283).	*					
102	„ ramosissima, d'Orb. (1, pl. 618) .	*					*
103	„ Sarthacensis, d'Orb. (1, pl. 619) .	*					
104	„ annulata, Rss. (Cricopora), Böhm. Kreide, pl. 14).						
105	„ echinata, Rss. (Pustulopora) (*l. c.*, pl. 14, fig. 4).						
106	„ neocomiensis, d'Orb. (13, p. 262) .		*				
107	„ gigantopora, Vine (13, p. 262 and 12, p. 8).		*				
108	„ pustulosa, Goldf. (Lonsd., 6, pl. 18A, fig. 8).						*
109	„ dendroidea, Keeping (Foss. Upware, &c., pl. 7, fig. 12).	*					
110	„ linearis ? d'Orb. (1, pl. 622, figs. 5–7).						*
	Clinopora, Marsson (7, p. 24).						
111	„ costulata, Marss. (7, pl. 2, fig. 2) .						*
112	„ lineata, Beissel (7, p. 24, pl. 2, fig. 2)						*
113	„ „ var. striatopora, Vine (12, pl. 1, fig. 5)		*	*			
	Spiropora, Lam. (2, p. 263).						*
114	„ verticillata ? Goldf. = Idmonea Comptoniana, Mant. 'Medals,' p. 284, fig. 14.						*
115	„ macropora, d'Orb. (1, pl. 754, fig. 754)						*
116	„ Jessoni, Vine (12, p. 6, pl. i., fig. 6) (Entalophora).		*				*
117	„ micropora, d'Orb. (1, pl. 754) . .						*
118	„ Cenomana, d'Orb. (present report) (non Entalophora, *id.*).						*
	Bidiastopora, d'Orb. (1, p. 798, pl. 2, p. 367).						
119	„ Mariæ, d'Orb. (1, pl. 755, fig. 13–15).						*
*120	„ lamellosa, d'Orb. (Elea, d'Orb., 1, p. 632).					*	
	Sulcocava, d'Orb.						
121	„ sulcata ? d'Orb. (1, p. 1020, pl. 789, figs. 1–3).						*
	Petalopora, Lonsdale (6, p. 285).						
122	„ pulchella, Lonsd. (6, pl. 18A, figs. 7–7*h*).					*	*
123	„ „ forma Clavicavea regularis, d'Orb. (1, pl. 773).						*
124	„ „ „ Cavea costata, d'Orb. (1, pl. 774).						*

[1] Whitaker, *Geology, London, &c.*, p. 80.

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk
	Sub-order CYCLOSTOMATA, Busk—*cont.*						
125	Petalopora pulchella, forma Cavea regularis, d'Orb. (1, pl. 774).						*
126	„ „ „ „ appendiculata, d'Orb. (1, pl. 774).						*
127	„ „ „ „ flexuosa, d'Orb. (1, pl. 774).						*
	Heteropora, Blainv. (2, p. 369).						
128	„ tenera, Hag. (4, pl. 5, fig. 14) .	*					
129	„ mamillata, d'Orb. (1, pl. 800, figs. 3–7).	*					
130	„ variabilis (Multicrescis, d'Orb., 1, pl. 800, fig. 3–7).	*					
*131	„ dichotoma, Blainv. (Man. d. Act., p. 417).					*	
132	„ cryptopora, Goldf. (Morris' Catalogue).			*	*		
133	„ clavula, Michelin (1, pl. 1070) .	*					
134	„ major, Keeping (Foss. Upware, &c., pl. vii., fig. 18).	*					
	„ (Zonopora, d'Orb.).						
135	„ undata, d'Orb. (1, pl. 771, fig. 14) .	*					
136	„ variabilis, d'Orb. (Vine, 16, p. 482)						
137	„ irregularis, d'Orb. (Vine, 16, p. 482)				*		
138	„ Ligeriensis (Multizonopora), d'Orb. (1, pl. 772).						
139	„ ramosa, Röm., „ Keeping, Foss. Upware.	*					
	„ (Clausa, d'Orb. p. 893).						
140	„ obliqua, d'Orb. (1, pl. 623) . .						*
141	„ irregularis, d'Orb. (1, pl. 624) .						*
142	„ Francqana, d'Orb. (1, pl. 766) .					*	*
143	„ micropora, d'Orb. (1, pl. 624) . .					*	
144	„ ? papularium (Atagma), Lonsd. (6, pl. 18B, fig. 6).						
	„ (Sparsicavea, d'Orb. 2).						
145	„ carantina, d'Orb. (2, 372, 1, pl.) .					*	
146	„ Francqana, d'Orb. (1, pl. 775) .					*	
147	„ (Nodocrescis) annulata, Keep., Foss. Upware (pl. 7, fig. 16).	*					
148	„ (Multicrescis) arbuscula, Keep., *ibid.* (pl. 7, fig. 171).	*					
149	„ „ digitata? Mich., *ibid.* p. 142.	*					
150	„ „ mamillata, d'Orb. (1, p. 1076).	*			*		
151	„ „ variabilis, d'Orb.				*		
152	„ sp. or var. new						
	Cavarinella, Marsson (7, p. 19).						
153	„ ramosa, Hag. (Marss., 7, p. 19) .						*

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk
	Sub-order CYCLOSTOMATA, Busk—*cont.*						
	Peripora, d'Orb. (1, p. 701).						
154	„ pseudospiralis, Mich. (1, p. 703) .	*					
	Bitubigera, d'Orb. (1, p. 748).						
155	„ cribriformis, Vine (present report) .						*
	Desmepora, Lonsdale (6, p. 281).						
156	„ semicylindrica, Lonsd. (6, pl. 18A, figs. 6–6*e*.						*
	Semicytis, d'Orb. (Osculipora pars, 1847, p. 1048)						?
157	„ rugosa, d'Orb. (1, 1049, pl. 795, figs. 1–7).						?
158	„ sp. (Francqana?), d'Orb. (1, pl. 794)						*
159	„ plebeia (Osculipora), Novák (12, p. 13)			*			
	Umbrellina, Reuss (Clypeina, ? Lonsd.; Lichenopora, Vine).						
160	„ tubæformis, Lonsd. (6, pl. 18A, fig. 4)						*
161	„ paucipora, Vine (Lichenopora, Vine, 11, p. 853).		*	*			
	Apsendesia, Lamx. (Unitubigera and Actinopora).						
162	„ papyracea, d'Orb. (1, pl. 643; 2, p. 381.				*		*
163	„ Gaudryana, d'Orb. (1, pl. 643) .						*
164	„ radians (Lopholepis), Hag. (4, pl. 3, fig. 11).	*					
165	„ collis (Actinopora), d'Orb. (1, p. 9)				*		
166	„ diademoides, d'Orb. (1, pl. 643) .						W[1]
	Lichenopora (d'Orb., 1).						
167	„ dilatata (Bicavea), d'Orb. (1, p. 956, pl. 776, fig. 34).						W[1]
168	„ organizans, d'Orb. (Radiotubigera, p. 971).						*
169	„ neocomiensis, d'Orb. (1, p. 683) .	*					
170	„ heteropora, Röm. (Radiopora), (1, pl. 781).	*					
171	„ Huotiana, Mich. (Radiopora bulbosa, d'Orb. (1, pl. 650).	*					
	Reptomulticava (pars), d'Orb.						
172	„ mamillata? d'Orb. (1, pl. 794). Young examples.						*
173	„ collis, d'Orb. (Vine, 15, p. 481)	*			*		
174	„ mamilla, d'Orb. (1, pl. 793) .						
175	„ simplex, d'Orb. (Vine, 15, 481) .				*		
176	„ favus, Seeley (Vine, 17, p. 294)						
177	„ radiata and var. (Vine, 12, p. 11).		*				
	Stelocavea, d'Orb. (1, p. 967.						
178	„ cultrata, d'Orb. (1, pl. 777) . .						
	Reptomultisparsa, d'Orb. (1, p. 875).						
179	„ hamiana, Keeping (Foss. Upware, &c., p. 137).	*					
	Homœosolen, Lonsd. (6, p. 307).						
180	„ ramulosus, Lonsd. (6, pl. 18B, fig. 3).						*

[1] Whitaker, *Geol. Lond.*, p. 80.

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk	
	Sub-order CYCLOSTOMATA, Busk—*cont.*							
181	Homœosolen ramulosus, var. Lonsd. (6, pl. 18B, figs. 4, 5).						*	
182	„ aculeatus, (Truncatula) d'Orb. (1, pl. 796).						*	
183	„ alternatus, (Truncatula) d'Orb. (1, pl. 797).						*	
184	„ carinatus, (Truncatula) d'Orb. (1, pl. 797).							
	Truncatula, Hag. (4, p. 34, 2, p. 385).							
185	„ subpinnata, d'Orb. (1, pl. 796) .						*	
186	„ pinnata, Rom., d'Orb. (1, p. 1053) .					*		
187	„ tetragona, d'Orb. (1, pl. 796) . .						*	
188	„ repens, Hag., or var. (Vine, 12 and 13)							
	Semicea, d'Orb. (1, p. 1007).							
189	„ lamellosa, d'Orb. (1, p. 1008, pl. 787, figs. 17–20).						*	
190	„ Cenomana, d'Orb. (Reptocea 1, p. 1009).							
191	„ ? lobosa Keeping (Reptocea), (Foss. Upware, &c., pl. 7, fig. 15).							
	Ceriopora, Goldfuss (pars)							
192	„ micropora, Goldf., Petrif., pl. 10, fig. 4.						*	
193	„ nodosa, Keeping (Foss. Upware, &c., pl. 7, fig. 14).							
194	„ Raulini (Echinocava, Keep., *l. c.*, p. 139).	*						
195	„ irregularis, d'Orb. (1, p. 1018) . .	*						
196	„ polymorpha, Goldf. (d'Orb., 1, p. 1034).	*						
197	„ avellana, Michel (d'Orb., 1, p. 1018).	*						
198	„ mamillosa, Röm. (d'Orb., 1, p. 1015).	*						
199	„ cavernosa, Hag. (see Bib., 17, p. 284)	*						
200	„ ramulosa (Ceriocava Eth.), Gault. .							
201	„ spongites, Goldf. (Wiltshire, Red Chalk) (see Bibl., 17, p. 293.)							
	Sub-order CHEILOSTOMATA, Busk.							
	Vincularia, d'Or. = (Cellaria), (d'Or., 1, pp. 23–27)							
202	„ cactiformis, d'Orb. (1, p. 29, pl. 651, figs. 1–4).						*	
203	„ inæqualis, d'Orb. (1, p. 30, pl. 651, figs. 5–8).							
204	„ oculata (Planicellaria, *id.*, d'Orb., 1, pl. 653).							Gr.[1]
205	„ cretacea, d'Orb. (1, pl. 600, figs. 17–19).						*	Gr.
206	„ regularis, d'Orb. (1, pl. 601, figs. 1–3).						*	
207	„ „ forma Santonensis, d'Orb. (1, pl. 656, fig. 2).						*	Gr.
208	„ areolata, d'Orb. (4, pl. 6, fig. 12) .						*	
209	„ undata, d'Orb. (1, pl. 656, fig. 11) .						*	
210	„ Gaudryana, d'Orb. (1, pl. 682, figs. 1–3).						*	
211	„ perangusta, d'Orb. (1, pl. 658, fig. 11)							Gr.

[1] Gr. Gravesend.

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk	—
	Sub-order CHEILOSTOMATA, Busk—*cont.*							
212	Vincularia Francqana, d'Orb. (1, pl. 681) . .						*	S[1]
213	„ excavata, d'Orb. (1, pl. 654) . .						*	S
214	„ simplex, d'Orb. (1, *Vincularina*, pl. 682).						*	S
215	„ Bronnii, Reuss, Böhm. Kreide., pl. 15, fig. 30).			*			*	S
	Membranipora, Blainville = Biflustra, d'Orb.							
216	„ argus, d'Orb. (1, pl. 689, figs. 1–4).						*	
217	„ pygmæa ? d'Orb. (1, pl. 688, figs. 16–18).						*	
218	„ pulchella, d'Orb. (1, pl. 690, figs. 1–3).						*	
219	„ pauperata, d'Orb. (1, pl. 692) . = Flustrina, d'Orb. (1, p. 298).						*	S
220	„ pulchella, d'Orb. (1, p. 256, pl. 690, figs. 1–3).						*	
221	„ „ var. granulosa, Vine (present report).						*	
222	„ irregularis, d'Orb. (1, pl. 702, fig. 14) .						*	
223	„ obliqua (Filiflustrellaria), d'Orb. (1, pl. 723).				*			
224	„ fragilis (Flustrellaria), d'Orb. (1, pl. 723).				*			
225	„ granulosa „ d'Orb. (1, pl. 725).						*	
226	„ confusa „ d'Orb. (1. pl. 725, figs. 9–12).						*	
227	„ marginata (Semiflustrina), d'Orb. (1, pl. 733).						*	
228	„ monilifera „ d'Orb, (1, pl. 722).						*	
229	„ tuberosa, Novák, var., Böhm. Kreide. (pl. 1, fig. 1).						*	S
230	„ elliptica, Hag., sp. Novák, Böhm. Kreide. (pl. 2, figs. 11–16).						*	S
231	„ cretacea, var. Francqana, d'Orb. (Vine, 13, p. 271).							
232	„ dumerilla, var. Cantabrigensis, Vine (12, p. 14).		*					
233	„ gaultina, Vine (15, p. 484, pl. 19, fig. 13) (Gault form).				*			
234	„ dispersa (Hippothoa) Mars. (7, pl. 9, fig. 9).							
235	„ simplex, d'Orb. (Hippothoa) (1, p. 385, pl. 711, figs. 5–8).							
236	„ clathrata, Rss. (unique) (8, p. 102, pl. 24, fig. 8).							S
237	„ rimosa (Micropora ?) (non Eschara, Marsson) (present report).							
238	„ Delarueana (non Eschara), d'Orb. (present report).						*	

[1] S. Salisbury.

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk	
	Sub-order CHEILOSTOMATA, Busk—*cont.*							
239	Membranipora arborea (Semieschara), d'Orb. (1, pl. 710).						W[1]	
240	„ Normaniana, d'Orb. (1, pl. 607)						W[1]	
	Micropora, Gray = Marginaria, Lonsd.							
241	„ Roemeri, Lonsd. (6, pl. 18B, fig. 7, &c.)						*	
242	„ Roemeri? var. A, with short avicularia.						*	
243	„ „ ? var. B, with long avicularia.							
244	„ intricata, Lonsd. = Escharina, Lonsdale (6, 18B, fig. 8).						*	
245	„ ? simplex (Escharina, d'Orb.) (1, pl. 605, figs. 10, 11).						*	
	Reptoescharellina, d'Orb. (1, p. 451 = *Escharellina* plates).						*	
246	„ oceani, d'Orb. (1, p. 454, pl. 605, figs. 14, 15).							
	Microporella, Hincks (Brit. Marine Polyzoa, p. 204).						*	
247	„ antiquata, Vine (11, pl. 2, fig. 11).		*					
	Cribrilina, Hincks, Brit. Marine Polyzoa (p. 184).							
248	„ linearis, Vine (present report) . .						*	
249	„ fragilis (Semiescharapora, d'Orb.) (1, pl. 717, fig. 9).						*	
250	„ brevis „ „ (1, pl. 718).						*	S[2]
251	„ flabellata (Semieschara, d'Orb.) (1, pl. 708).						*	S
252	„ pygmæa (Reptescharella, d'Orb.) (1, pl. 716).						*	S
253	„ horrida (Disteginopora, d'Orb.) (1, pl. 603 and 687 *bis*).						*	S
254	„ nitidiformis, sp. n. (21) . . .						*	
	Porina, d'Orb. (Marsson) (7, p. 84).							
255	„ pustulosa, Marsson (7, pl. 8, fig. 9) .						*	S
256	„ cincta (Membranipora) Reuss (8, p. 102, pl. 4, fig. 7).						*	S
	Epidictyon, Marsson = Siphoniotyphlus, Lonsd.							
257	„ plumatus, Lonsd. (6, pl. 18B, figs. 2, 2A).		*	*			*?	
258	„ tenue, Hagenow (present report) .						*	
	Melicertites Röm. (Nodelea and Melicertites, Auct.).							
259	„ Dollfussi, Perg. (2, p. 359, pl. xii., fig. 4).						*	
260	„ semiclausa, Mich. (see Waters, 18, p. 52).						*	
261	„ semiclausa, forma, Lorieri, d'Orb. (1, pl. 601, fig. 18–20).						*	
262	„ Meudonensis (Entalophora, Morris' Catalogue).	*						
263	„ gracilis (Entalophora, Vine, 14, p. 18), Louth.	*					*	
264	„ Upwarensis, Keeping (Foss. Upw. *l. c.*, pl. 7, fig. 15).	*						

[1] Whitaker, *Geol. Lon l.*, p. 80.

[2] S. Salisbury.

Nos.	Genera and Species	Neocomian	Camb. Greensand	Chalk Detritus	Red Chalk	Up. Greensand	Upper Chalk	—
	Sub-order CHEILOSTOMATA, Busk—*cont.*							
265	Melicertites (Nodelea) propinqua, Mars. (8, pl. 5, fig. 1).						*	
266	„ (Claviclausa), globulosa, d'Orb. (1, pl. 765).						*	
	Eschara, Lam. (d'Orb. for history, 1, pp. 96–104).							
267	„ cleon, d'Orb. typica (1, pl. 671, figs. 8–11).						*	
268	„ „ var. Frondescent, with avicularia.						* * *	
269	„ cypræa, d'Orb. (1, pl. 675, fig. 1) . .							
270	„ sexangularis (Morris' Catalogue) . .							
271	„ Claudia, d'Orb. (1, pl. 671 and 675) (near)						*	
272	„ Cybele, d'Orb. (1, pl. 674) „						*	
*273	„ cancellata, Goldf., Petrif., pl. 8, fig. 13 (Morris' Catalogue).						*	Gr.[1]
*274	„ disticha, Goldf., Petrif., pl. 30, fig. 8 (Morris' Catalogue).						*	Gr.
*275	„ pyriformis, Goldf., Petrif., pl. 8, fig. 10 (Morris' Catalogue).						*	Gr.
*276	„ Lonsdalei, M. Ed., Ann. Sc. Nat. (Morris' Catalogue).						*	
277	„ Danæ, d'Orb. (1, pl. 675) . . .						*	S[2]
278	„ rimosa, Mars. (7, pl. 761) . . .						* *	S
279	„ Delarueana, d'Orb. (1, pls. 602–673) .						*	S
	Discoflustrellaria, d'Orb.							
280	„ doma, d'Orb. (1, pl. 722, figs. 6–10) .						*	S
	Lunulites, Lam., d'Orb. (1, p. 346).							
281	„ cretaceus, Defr. (d'Orb., 1, pl. 704, fig. 2)						*	
282	„ rosaceus, d'Orb. (1, pl. 705) . .						*	S
	Stichopora, Hagenow (see 1, p. 360) . .							
283	„ clypeata, Hag. (4, p. 100, pl. 12, fig. 14).						*	

I have now reviewed and reported upon the whole of the British Fossil Polyzoa known to me. From certain indications that have come to my knowledge, the reports have been helpful in many ways to specialists: for this I feel grateful. For my many imperfections or defects I must apologise, but at the same time my thanks are given to Professor T. Rupert Jones, F.R.S., and to Dr. Henry Woodward, F.R.S., of the British Museum, for many kindly suggestions and efficient aid during the progress of my work. My thanks are due also to those friends who have willingly acted with me as the Committee. To the General Committee of the British Association my thanks are especially due for help rendered and encouragement given from time to time whilst I have been engaged in the compilation of the seven reports—including the present one—on Fossil Polyzoa, which are now completed.

[1] Gr. Gravesend. [2] S. Salisbury.

Report of the Committee, consisting of Messrs. H. Bauerman, F. W. Rudler, *and* J. J. H. Teall, *and* Dr. H. J. Johnston-Lavis, *appointed for the investigation of the Volcanic Phenomena of Vesuvius and its Neighbourhood.* (*Drawn up by* Dr. Johnston-Lavis.)

Since the last report nearly all the tunnelling for the great main sewer is complete, and few additional facts of interest have come to light. Several little problems of purely local geology have, however, been solved. In the lower sewer collector, beneath the tramway tunnel of Naples, a peculiar grey trachytic mass has been met with, and was penetrated for a short distance. On account of a lawsuit the works do not progress. The mass, however, is of considerable interest, as it is below the great yellow tuff of Posilipo and Naples. The rock was ejected rapidly in very pasty or almost solid fragments, which in some cases blended with the others thrown out just before and after, and are flattened out in a pipernoid manner. At other points the fragments are broken, mixed with dust, and consequently incoherent. When this deposit is cut through, it will probably confirm my theory regarding the piperno of Pianura and Soccavo, as being the result of lumps of lava ejected in great blobs, which falling quite hot around the vent have become resoldered together, and have even flowed a little.

Very high temperatures have been met with in the tunnel near the Solfatara, where I registered myself 59° C. on a day that the workmen considered a very fresh one for the workings, *i.e.*, with a high barometer still rising.

The statement made many years since by Professor A. Scacchi, that fragments of leucitic lavas had been found by him at the Foce di Fusaro, near the Torre Gavetta, led me to suspect the existence there of the Museum breccia. On examining the locality this was confirmed, and, in fact, the whole sea cliff of Mte. di Procida exhibits a most interesting though complex section of the volcanic series of the Phlegræan Fields.

We have there a series of trachytes forming the base of the section, very various in texture, and often covered with thick beds of their own scoriæ, which are often consolidated into a kind of trachytic breccia quite analogous to the 'sperrone' of the Alban hills. This is overlaid by fine lapilli and pumice beds, which vary very much in thickness. Lying unconformably upon these are irregular buried outliers of the grey pipernoid tuff of the region. In one place the pipernoid tuff is seen in section as an exceedingly obtuse V-shaped mass, having choked an old valley, and possessing the following characters: The black scoria fragments are very slightly, if at all, flattened, are very spongy, are of good size, and form an important constituent of the deposit. From this we can conclude that the distance would well correspond with my supposed eruptive mouth to the S.S.W. of Camaldoli, not very far from the Lago d'Agnano, from which I believe issued the piperno and the greater part of the pipernoid tuff of the Campania. The distance was, in fact, such as to allow time for only the lighter pieces of scoriæ, the equivalent to the black flackers of the piperno, to travel so far, and these to be so cooled that when they fell they were too rigid to be flattened out by the impact.

This grey pipernoid tuff has here suffered much denudation, for in

many places it is quite removed. Towards Torre Gavetta the 'Museum' breccia is well developed, being composed of very large blocks of the numerous varied rocks, followed by beds of the woody pumice, woody looking scoriæ and scoriaceous black centred vitreous trachyte fragments and pumice. Lying with very marked unconformability upon it is a great thick bed of the compact yellow tuff, either derived from Campagnone or the neighbouring cone, a slice of which forms Misenum. In this section we have splendidly exhibited many of the great geological records in the history of this remarkable volcanic region. Each of these stages is defined from those above and below it by more or less long periods, during which in some cases very extensive denudation had taken place. At this point also I am satisfied we have products of the eruptions of the Procida and neighbouring centres interstratified with those of the mainland, and in which I hope in time to work out the relative chronology.

The discoveries, which in so striking a manner confirm my conclusions regarding the highly complex stratigraphy of this region, induced me once more to examine in detail that isolated eminence upon which once stood the renowned Greek town of Cumæ, founded about 1000 B.C.

Time has favoured the geologist, for here, however much the archæologist may grieve, it has once more exposed to human eyes sections that for many centuries were hidden by buildings, but which reveal the fact that those very rocks that as geologists we look upon as very recent had nearly 3,000 years ago much the same characters as now. The pumices that form the uppermost yellow tuff had then already been converted into a rock which those early colonists cut out and used for the construction of their walls. When we first visit Cumæ, and our thoughts wander back through historic time, we are impressed by the human associations with this hill for such a long period; but when we return with our eyes and minds geologically cultured, the ancient Greek town sinks into insignificance by the side of the physical history of the mound it stood upon, when we remember that not only this mound, but the whole region is post-Pliocene in age.

The foundation of the Cumean hill is the well-known trachyte rich in inclusions of sodalite, of amphibole, and I have detected not uncommonly crystals of fayalite. Were it more vesicular it would very much resemble the western mass of trachyte of the Cumana railway tunnel at the back of Naples.

Above this come some pumice and dust beds, which are probably the equivalent of the Rione Amedeo tuffs. Superposed on this we find a dirty grey pipernoid tuff which shows much *remaniement*. The Museum breccia is well represented in patches, and is overlaid by a bed of vitreous trachyte produced by the resoldering of the falling masses into one solid stratum, where the surface was flat, but where an incline is the fragments have remained separate. The whole is capped by the compact yellow tuff. There are also some minor pumice and dust beds which require further working out.

The trachyte seems to have oozed forth in a highly pasty condition, breaking up its scoriaceous surface, which rolled down the sides of the dome-shaped mass, and by pressure and heat from the main mass became again soldered together—in fact, a sort of regelation. The brecciated structure is undiscernible in hand specimens or under the microscope, but is well etched out by meteoric agencies. Each of the deposits mentioned above

shows more or less unconformability, which corresponds as they themselves do with those beds of the Monte Santo Funicular Railway, the Cumana Railway, Pianura, Soccavo, Monte di Procida, Nocera, Castellamare, St. Agata, Capri, Caserta, &c., which I have described in other reports and papers.

These are the principal sections which record the later geological history of the Phlegræan Fields, and from which I have been able to unravel the stratigraphy of the highly complex Neapolitan volcanic region. So far it has been explained only in these reports and other disjointed papers, but before long I hope to be able to place before the scientific world a far more detailed description of one of the most interesting as well as the most classic and accessible volcanic regions of the world.

Before quitting the subject, however, I wish to call attention to the confirmation that the sections mentioned in this report afford of my explanation of the piperno and pipernoid structure in general. We see distinctly that the variation in colour and texture of the two constituents of the piperno, which chemically are identical, is simply due to the greater saturation with H_2O of one portion of the magma than the other in the old chimney of the volcano at the time of the eruption. The consequence was that the more aquiferous part was erupted as a fine dust, and the less aquiferous, more coherent magma was ejected in large fragments or more or less scoriaceous cakes, which lost their heat the more slowly, the less H_2O contained in them there was to expand. The densest, and at the same time the slowest to cool, fell near the eruptive mouth, flattened out, squeezed out those beneath them, and were squeezed out by those above them, forming, with the included dust, the compact piperno in which the foliated structure is most developed towards the W. end of the Soccavo section, where the nearest existing remnant to the old crater is now preserved, and where the inclination was greatest, and consequently where actually slight flow took place. The more scoriaceous of these lava cakes were carried to greater distances, so that as we travel away from the eruptive axis we find, first, that the black fragments become less markedly flattened because they cooled more rapidly from expansion, and also because they travelled farther, until they no longer show flattening parallel to the bedding more than what would be due to any of them being accidentally of flattened or elongated form, and so lying flat on the surface on which they fell; second, we find that as their radial distance from the eruptive axis increased, the fragments at first get lighter; and third, when the limit of lightness and cohesion is reached, they get smaller and smaller, so that at Roccamonfina and Salerno the pipernoid tuff is chiefly composed of the grey dust with only few and minute fragments of black scoriæ. This seems to have been modified by strong winds, and possibly by the eruption taking place along a cleft much like that formed in the late Tarawera eruption, or as in many cases in Iceland, such as the Skaptar outburst, though most of the latter locality do not belong to explosive types of eruptions.

There is in Iceland, at Krisuvik, the principal one of several crater lakes which exhibits in a striking manner the resoldering together of ejected fragments, into what might at first appear to be a true lava stream. I allude to the Groenavatn, in which we have an almost circular conical hollow nearly filled with water. There is only a very low ring around it, composed of *accidental* ejectamenta, being nothing more than the ejected fragments of the materials, through which it was drilled, with practically

no essential ejecta, except on one side, where we have a mass of rock that looks like a lava stream. It seems there must have been at the moment of the eruption a very strong wind which carried all the lava fragments in one direction, and as they fell they blended together into one fairly uniform mass, the components of which are only faintly indicated by a slight variation in colour, somewhat like piperno, but not so well marked. The top and bottom are less coherent, for at the bottom the fragments fell on cold ground, whilst the top, although falling on the hot mass beneath, could not be pressed into contact with it by later falls. No doubt also the explosions were feebler towards the end and the interval longer between the fall of the last fragments.

We find exactly the same thing in the piperno, namely, a spongy tufaceous-like bottom and top. Besides this, the lulls and accentuations of the explosive action are well marked, as well as the time that large masses of the crater edges fell in and were re-ejected. At one time the eruptive action seems to have been arrested, and the partly or entirely consolidated plug was blown out into fragments and deposited amongst the piperno.

Vesuvius has since the last report, up to the time of my last visit in May, shown very little variation. It will be remembered that lava was issuing at the site of the eruption of June 7, 1891, at the foot of the great cone, more than three hundred metres below the summit at the junction with the Atrio del Cavallo, and nearly opposite the Punta del Nasone. This outpour practically never stopped—at times it increased to no inconsiderable quantities, but flowed only a short distance, on account of the low gradient, tending to pile itself up into a mound. On other occasions it seemed to become almost arrested, but it never practically stopped. The consequence of all this was that at the foot of the great cone in the Atrio, during the year from June 1891 to June 1892, a tremendous mound or low-pitched buttress had been built up, so that its highest part I estimate to be 20 m. above the old floor of the Atrio. This thickened away in all directions, but even under the escarpment of Somma, the present floor stands for considerable distances over 5 m. higher. In consequence of this many of the dyke numbers which cost me so much labour to put up some years since have been covered over. These I hope to be able to replace this winter, and to repaint all the rest that are now becoming obliterated. It will be remembered that these numbers correspond with the dykes figured in my geological map of Vesuvius, and all collectors now adopt these numbers to indicate the locality of the dyke from which the specimens are obtained. Professor Bassani has added a new and complete collection of these interesting dyke rocks to the Naples Museum, and has arranged them according to my numbering. The great importance of maintaining this numbering intact will be seen.

The actual details of the variations in the activity are as follows. During the summer and autumn of 1891 more crumbling in of the crater edges took place, followed by black sand and dust-charged vapour. The outpour of lava from the base of the cone in the Atrio from time to time almost stopped, to be followed again by fresh gushes. On the first day of December a marked extension took place to the south and south-east of the crater by the further crumbling in of its edges. On the last day of the old year and commencement of 1892 the outflow was much accentuated. During January and February few variations were observable,

but on March 17 and 18 slight reflection from the crater was visible for the first time for nearly a year, showing the rise of the lava in the chimney, due certainly in part from blocking of the lateral channel, as the outflow of lava below was markedly diminished. On the 21st the activity at the crater was distinctly at the first degree, but on the 22nd the second degree was attained. On that evening, however, a gush of lava showed the removal of the lateral obstruction to its outflow, and the central activity so diminished that the following night no reflection was visible. On March 29 and 31 the crater again showed the first degree of activity.

This was followed during the first week of April by a fresh outflow of lava, which still more increased during the next week. During the first four days of the month feeble reflection was from time to time visible from the crater. On the 12th, black dusty smoke was puffed out from time to time. On visiting the Atrio, I found the lava that flowed had formed the mound above spoken of, surmounted by fumaroles.

During the night of May 3–4 fresh portions of the crater wall collapsed and blocked the vent, so that during the following day hardly any vapour crowned the summit of the volcano. By the next day the increased tension of the vapour was sufficient for it to force its way through the obstruction, and much black sandy smoke escaped during the 5th, 6th, 7th, and 8th. Obstructing masses that had detached themselves from the crater sides again plugged the vent on the 27th and 28th; the next day dark, sandy, and dusty smoke was emitted.

The flowing lava showed few new phenomena, with the exception of the fine examples of conical and tubular spiracles formed above the lava exit at the same locality, being above one set figured in the last report, now buried.

One is unique on account of its curved overhanging form. As was seen in the photograph exhibited, it was ejected at the highest point of the new lava, and quite at the foot of the great Vesuvian cone. I can only explain its inclination at the lower part, by supposing that the vapour and lava fragments were projected upwards and outwards in a plane radial to the volcanic chimney which corresponds with the orientation of the fumarole. This lateral projection seems to have gone on for some time, so that many of the blobs of lava blown out fell, and formed a support for the inclined tube. As the blasts escaped more feebly the edges of the mouth became more solid, and so the lower lip diverted the column more in an upright direction, until the growth became almost vertical. The whole effect is to produce a large mass somewhat resembling a recumbent animal with its neck and head erect.

About twenty yards more distant from the foot of the cone was another large, obtuse, conical-shaped fumarole, which had been broken away on one side, and well exhibited the dome-like interior covered by stalactitic lava, as shown in a photograph exhibited. These two specimens constitute very fine examples of the spiracles which may be built up on the surface of a coarsely crystalline lava, such as that now issuing from Vesuvius. They differ very considerably from those described and illustrated by Dana and others from Hawaii, and from those formed on acid lavas at Réunion, of which one or two figures have been published.

At the summit of the great cone few changes have occurred beyond the further enlargement of the crater. When slips took place from the edges, dark dust-laden vapour was puffed out from time to time. On one or two occasions the lava rose sufficiently high in the chimney, combined

with the sufficiently strong explosions, to project a few lava cakes beyond the crater edges. The bottom of the crater has been invisible owing to the large amount of vapour present on each occasion when I visited the mountain summit.

Since I quitted Naples an actual crateret has opened in the Atrio at the point where these fumaroles stood, and several gushes of lava have taken place. I shall more fully report on these new phases on my return to Naples.

Report of the Committee, consisting of Mr. G. J. Symons, Mr. C. Davison (*Secretary*), Sir F. J. Bramwell, Mr. E. A. Cowper, Professor G. H. Darwin, Professor J. A. Ewing, Mr. Isaac Roberts, Mr. Thomas Gray, Dr. John Evans, Professors J. Prestwich, E. Hull, G. A. Lebour, R. Meldola, *and* J. W. Judd, Mr. M. Walton Brown, *and* Mr. J. Glaisher, *appointed to consider the advisability and desirability of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions.*

During the past year the attention of the committee has been directed to ascertaining what instruments have been devised in other countries suitable for the work with which your committee is charged. They believe that that list is now nearly complete, and in their next report they propose to fully describe and illustrate these devices, as they are sure that such a collection of descriptions would be extremely useful.

This list will certainly contain the following instruments, and probably others of a simpler and less expensive character.

1. The *nadirane* erected by M. Wolf in the observatory of Paris.

2. The *pendulum with double-suspension mirror* employed by Messrs. G. H. and H. Darwin at Cambridge in their attempt to determine the lunar disturbance of gravity.

3. The *tromometer* used by P. Bertelli at Florence, and by other observers in Italy and Switzerland.

4. The *tremor recorder* of Professor J. Milne used by him in Japan.

Mr. Horace Darwin has recently invented another form of pendulum, smaller and less delicate than the one referred to above. This instrument has been made by the Cambridge Scientific Instrument Company, and Mr. Darwin has generously offered to place it temporarily at the disposal of the committee. Experiments will be made with it shortly, an account of which the committee hope to give in their next report.

The committee request that they be reappointed, with the addition of Professor C. G. Knott and Professor J. H. Poynting.

Report of the Committee, consisting of Dr. P. L. Sclater, Professor Ray Lankester, Professor Cossar Ewart, Professor M. Foster, Mr. A. Sedgwick, Professor A. M. Marshall, *and* Mr. Percy Sladen (*Secretary*), *to appoint* Mr. Willey *to investigate the Morphology of the Ascidians at the Zoological Station at Naples, or, failing this, to appoint some other competent investigator to carry on a definite piece of work at the Zoological Station at Naples approved by the Council.*

Your Committee have the pleasure to report that the table at the Naples Zoological Station hired by the British Association has been continuously occupied since the beginning of October last by Mr. Arthur Willey. Mr. Willey, who is still in Naples and does not expect to complete his work before the middle of August, has furnished a preliminary report upon the investigations he has undertaken whilst occupying the table. The report in question is appended, and is one to be regarded with satisfaction.

The Committee have received an application for permission to use the table from Mr. Cecil Duncan, who proposes to investigate the effect of different rays of light upon Algæ containing different coloured pigments—a subject of great interest from both the chemical and the biological standpoint. Mr. Duncan proposes to commence work at Naples on August 15. This application has been unanimously approved by your Committee, and they trust that the Association will sanction the payment of the grant of 100*l*., as in previous years, for the hire of the table in the Zoological Station at Naples.

The importance of the work carried on by the Zoological Station at Naples and the admirable organisation of the institution for the purposes of research are now so universally recognised that your Committee feel it would be superfluous to recapitulate the advantages to the Association—and through the Association to all British naturalists—of maintaining the right to participate in this great international undertaking.

The details extracted from the general report of the Zoological Station, which have been courteously furnished by the officers of the Station, afford the most convincing evidence of the progress and success of the institution. The details referred to, which will be found at the end of this report, embrace lists (1) of the naturalists who have occupied tables since the last report; (2) of the works published during 1891 by naturalists who have worked at the Zoological Station; (3) of the specimens sent out by the Station during the past year.

The progress of the various publications undertaken by the Station is summarised as follows:—

1. Of the 'Fauna und Flora des Golfes von Neapel' the first three monographs mentioned in last year's report—viz., on 'Gammarini,' by Prof. Della Valle; on 'Balanoglossus,' by Prof. Spengel; and on 'Pelagic Copepoda,' by Dr. Giesbrecht—will probably be published at the end of the present or the beginning of the next year, the text and plates being now nearly ready. Each monograph will run to about 800 pages of text, with accompanying illustrations. The delay during the past year in the publication of this costly series of monographs has arisen solely from the

great extension of the works themselves. All who are acquainted with the monographs previously issued and with the character of the research involved will readily appreciate this circumstance. It is doubtful if any other similar institution has produced so large a series of works as those already published within the same time.

2. Of the 'Mittheilungen aus der Zoologischen Station zu Neapel,' vol. x., parts i. and ii., with 22 plates, have been published.

3. Of the 'Zoologischer Jahresbericht' the whole 'Bericht' for 1890 has been published.

4. Of the 'Guide to the Aquarium' a new English edition has been published. All four editions—English, German, Italian, and French—are now illustrated.

I. *Report on the Occupation of the Table.* By Mr. Arthur Willey.

I came to Naples with the object of studying Ascidian development from the point of view of the close relationship believed to exist between the Ascidians and *Amphioxus*. I had already made a study and published an account of the post embryonic development of *Amphioxus*,[1] which revealed certain fresh points of contact between the two groups, especially with regard to the behaviour of the endostyle. Having now had an opportunity of making personal observations on the development of some of the Ascidians, I have arrived at certain conclusions which differ considerably from the position which I assumed in the paper above quoted, and which I venture to think not only show the relations between the Ascidians and *Amphioxus* to be closer than was formerly supposed, but also render them more intelligible.

I attempted at the outset to obtain the embryos of *Appendicularia*, but after a long and wearisome search was unsuccessful, and accordingly turned my attention to the embryonic development of the curious and well-marked Ascidian, *Cynthia papillosa*, Linn., which spawned in the tanks in the month of November.

The eggs of this form are very opaque, and I had to make use of transverse, horizontal, and sagittal sections. There is a considerable quantity of yolk, and the gastrulation is preceded by what Davidoff calls a 'plakula-stage.' The mesoderm consists at first of an arc of cells lining the posterior wall of the blastopore. It does *not* form a ring surrounding the blastopore. It is easy to distinguish the mesodermal cells from the endodermal on account of the practical absence of yolk in the former, while in the latter cells the innumerable yolk spheres become very darkly stained with osmic acid. The notochord arises purely from the endoderm, and there is no question of a common 'Anlage' of mesoderm and notochord.

It is a curious fact that the eggs of this Ascidian only underwent segmentation at night, just as is the case with the eggs of *Amphioxus*, not that this is anything more than an analogy. Most of the young tadpoles of this species, while still enclosed within the vitelline membrane, instead of curving round ventrally, curved round dorsally. Whether it was a pathological phenomenon or whether it occurred as a variation, I cannot decide, but it is in any case interesting from the fact that the dorsal curvature was almost invariably accompanied by what may be

[1] See *Quart. Journ. Microsc. Sci.* vol. xxxii., March 1891.

described as a hypertrophy of the anterior end of the notochord, in that it either extended unusually far forwards, or, as was more frequently the case, it bent round sharply on itself in front.

The tail arises as a *solid outgrowth* from the body of the larva, containing the greater part of the notochord, some mesodermic elements in the form of two lateral plates of cells, and some endoderm in the shape of a median ventral cord of cells, two deep.

The intestine of Ascidians is in all probability entirely homologous with that of *Amphioxus*, including the possession of a cæcum; and its U-shaped curvature is apparently, in accordance with the reflections of Lang, to be correlated with the sessile habit of the Ascidians. An interesting parallel for this is afforded by the comparison of *Cephalodiscus* and *Balanoglossus*.

Being unable to rear the embryos of *Cynthia papillosa* beyond the tadpole stage, I commenced to work at the post-embryonic development of *Ciona intestinalis*. I have already sent up a short *résumé* of part of my researches on this form, together with some which I instituted on *Clavelina lepadiformis* for purposes of comparison, for publication in the 'Proceedings of the Royal Society.' The paper in question was read before the Royal Society on May 18 of this year (1892). It contained an account of what I called a *proboscis cavity*, which, on account of its primary relative position to the endostyle, I homologised with the head cavity or præ-oral cœlom, or, in short, proboscis cavity of *Amphioxus* taken in conjunction with the præ-oral pit.

In *Ciona* as in *Amphioxus* the primary axis of the endostyle is at right angles to its definitive axis, and it lies in both cases *tout-à-fait* anterior—that is to say, immediately behind the cavity of the proboscis. The latter structure in *Ciona* carries at its anterior extremity the three adhering papillæ.

The first four primary stigmata of *Ciona* arise on each side by subdivision of one gill-slit, and not, as van Beneden and Julin assumed in *Phallusia scabroïdes*, by separate perforations. This gill-slit I have called the true first gill-slit of Ascidians, and homologised the pair of them with the first pair of slits of *Amphioxus* which I have previously described as closing up in the course of the metamorphosis.

In *Ciona* the heart arises by the splitting apart of the two layers composing the septum, which at first divides the pericardium into two halves, while in *Clavelina*, as shown by van Beneden and Julin, the corresponding septum breaks down, and the heart forms by invagination of the dorsal wall of the pericardium.

In both *Clavelina* and *Ciona* the hypophysis is at first in free communication with the cerebral vesicle; it is, in fact, largely formed by constriction from the wall of this vesicle. This is in profound opposition to the account of van Beneden and Julin, who state that in *Clavelina* the hypophysis arises entirely by a cæcal outgrowth from the wall of the branchial cavity. I am absolutely at a loss to explain how they came to this result. My observations were first of all made on the larvæ of *Ciona*, where the organs are extremely small and difficult to interpret; but still I convinced myself of the true condition of things, and immediately assumed that in *Clavelina* the formation of the hypophysis occurred in a rather different manner, which could be explained by the great modification which *Clavelina* shows in its general development. When, however, I came to examine how matters stood in the larva of *Clavelina*, I saw at

once that the relations of the hypophysis to the cerebral vesicle were most emphatically the same as I had found them in *Ciona*.

In the case of *Clavelina* the difficulty is *not* to see the connection of the lumen of the hypophysis with the cerebral vesicle.

From the observations of Kowalewsky as well as from my own, I think it extremely probable that the opening of the hypophysis into the branchial cavity is really the neuroporus, which is carried inside with the stomodæal invagination. Further, from a consideration of their respective relations to the cerebral vesicle, I regard the hypophysis of Ascidians and the so-called 'olfactory pit' of *Amphioxus* as homologous structures.

The reason why the 'olfactory pit' of *Amphioxus* does not open into the buccal region of the pharynx is, that the mouth has been shifted from its primitive relation to the neuroporus by the remarkable forward extension of the notochord, the special character of which, necessitating a special explanation, was recognised fifty years ago by Kölliker.

Latterly the larvæ of *Amphioxus* have turned up in large quantities in the Bay of Naples, and I have been studying the distribution of the cranial nerves and the peripheral ganglion cells by means of the methyl-blue method of Ehrlich, by means of which it is possible to stain the living larvæ, especially the nervous tissue.

In this way also I have been able to control my former observations on the metamorphosis of the larva of *Amphioxus*.

I am about to publish a full account of the above researches in the 'Quarterly Journal of Microscopical Science.'

In conclusion, I beg to express my best thanks to the Committee of the British Association for appointing me to the use of the table at Naples.

II. *A List of Naturalists who have worked at the Zoological Station from the end of June* 1891 *to the end of June* 1892.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
622	Prof. S. Apáthy	Hungary	July 2, 1891	Oct. 9, 1891
623	Prof. A. Della Valle	Italy	„ 4, „	Nov. 2, „
624	Dr. R. Staderini	„	„ 6, „	Aug. 29, „
625	Dr. U. Rossi	„	„ 6, „	„ 29, „
626	Mr. D. Rossinsky	Russia	„ 15, „	„ 6, „
627	Dr. F. S. Monticelli	Italy	Aug. 1, „	—
628	Dr. G. Mazzarelli	„	„ 1, „	—
629	Prof. J. Steiner	Prussia	„ 10, „	Aug. 29, „
630	Dr. C. Crety	Italy	„ 11, „	Nov. 5, „
631	Prof. A. Goette	Strasburg	„ 16, „	Oct. 21, „
632	Dr. J. H. F. Kohlbrügge.	Holland	„ 21, „	Nov. 16, „
633	Dr. V. Häcker	Baden	„ 29, „	Oct. 26, „
634	Dr. E. Germano	Italy	Sept. 1, „	—
635	Dr. K. W. Zimmermann.	Academy, Berlin	„ 4, „	Oct. 8, „
636	Dr. L. Zoja	Italy	„ 7, „	„ 28, „
637	Dr. R. Zoja	„	„ 7, „	„ 28, „
638	Dr. H. Driesch	Hamburg	„ 28, „	Apr. 4, 1892
639	Dr. C. Herbst	Academy, Berlin	„ 28, „	„ 28, „
640	Dr. W. Müller	Prussia	Oct. 1, „	Feb. 25, „
641	Mr. E. W. MacBride	Cambridge	„ 5, „	—

II. A List of Naturalists—*continued.*

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
642	Mr. A. Willey	British Association	Oct. 8, 1891	—
643	Dr. O. Visart	Italy	Nov. 11, „	Jan. 15, 1892
644	Ten. A. Navarrete	Spain	Dec. 8, „	—
645	Dr. C. Pictet	Switzerland	„ 11, „	Mar. 21, „
646	Prof. G. Gilson	Belgium	„ 13, „	Apr. 12, „
647	Prof. W. Salensky	Russia	„ 15, „	„ 26, „
648	Dr. G. Cano	Italy	Jan. 1, 1892	—
649	Dr. A. Russo	„	„ 1, „	—
650	Dr. G. Jatta	„	„ 1, „	—
651	Dr. G. Raffaele	„	„ 1, „	—
652	Dr. R. Heymons	Prussia	„ 1, „	May 5, „
653	Dr. R. von Erlanger	Baden	„ 6, „	—
654	Dr. S. Bonaduce	Italy	„ 7, „	—
655	Cand. J. Hjort	Bavaria	„ 10, „	May 2, „
656	Prof. E. B. Wilson	Amer. 'Davis' Table	„ 11, „	—
657	Dr. A. Krupenin	Russia	„ 19, „	June 20, „
658	Dr. O. zur Strassen	Saxony	„ 29, „	—
659	Dr. G. Antipa	Zoological Station	Feb. 14, „	—
660	Prof. A. de Korotneff	Russia	„ 17, „	Mar. 2, „
661	Stud. A. Graber	Austria	Mar. 5, „	Apr. 6, „
662	Dr. F. Röhmann	Prussia	„ 5, „	„ 19, „
663	Dr. W. Nagel	Würtemberg	„ 15, „	„ 18, „
664	Prof. M. von Lenhossék.	Hungary	„ 16, „	„ 15, „
665	Dr. K. W. Zimmermann.	Prussia	„ 16, „	„ 28, „
666	Dr. R. Gottlieb	Austria	„ 19, „	„ 22, „
667	Dr. J. von Uexknell	Würtemberg	„ 19, „	May 17, „
668	Prof. W. von Schröder	Strasburg	„ 22, „	Apr. 14, „
669	Mr. H. Pollard	Oxford	„ 29, „	—
670	Dr. H. K. Corning	Austria	Apr. 6, „	May 10, „
671	Dr. A. Kreidl	„	„ 6, „	„ 20, „
672	Dr. O. Buchner	Würtemberg	„ 26, „	—
673	Dr. B. Dean	Bavaria	„ 27, „	June 3, „
674	Prof. G. von Koch	Hesse	May 17, „	—
675	Dr. V. Faussek	Russia	„ 20, „	—
676	Dr. D. Carazzi	Italy	„ 25, „	—
677	Prof. S. Apáthy	Hungary	June 9, „	—

III. *A List of Papers which have been published in the year* 1891 *by the Naturalists who have occupied Tables at the Zoological Station.*

Dr. O. Lubarsch . . Untersuchungen über die Ursachen der engeborenen und erworbenen Immunität. Berlin, 1891.

Dr. H. Griesbach . . Beiträge zur Histologie des Blutes. 'Arch. f. mikr. Anatomie,' Bd. 37, 1891.

Dr. W. Marcuse . . Beiträge zur Kenntniss des Stoffumsatzes in dem thätigen elektrischen Organ der Zitterrochen, &c. 'Inaug. Dissert.,' Breslau, 1891.

Prof. H. Ludwig . . Zur Entw.-Geschichte der Holothurien, I. 'Sitz. Ber. K. Preuss. Akad. d. Wiss.,' Berlin, 1891.

„ „ . . Zur Ent.-Geschichte der Holothurien, II. *Ibid.*

Dr. G. Cano . . Sviluppo postembrionale della Gebia, Axius, Callianassa, e Calliaxis. Morfologia dei Talassinidi. 'Boll. Soc. Nat. Napoli,' Anno 5, 1891.

Dr. G. Cano . .	Sviluppo postembrionale dei Dorippidei, Leucosiadi, Corystoidei e Grapsidi. 'Soc. Ital. delle Scienzi,' T. 8, 1891.
„ . . .	Sviluppo postembrionale dello Stenopus spinosus Risso. Studio morfologico. 'Boll. Soc. Nat. Napoli,' Anno 5, 1891.
Dr. J. Loeb . . .	Ueber Geotropismus bei Thieren. 'Arch. f. d. ges. Physiologie' (Pflüger), Bd. 49, 1891.
„ . . .	Ueber den Antheil der Hörnerven an den nach Gehirnverletzung auftretenden Zwangsbewegungen, &c. 'Pflüger's Archiv,' Bd. 50, 1891.
„ . . .	Untersuch. zur physiol. Morphologie der Thiere, II. 'Organbildung u. Wachsthum,' Würzburg, 1891.
Dr. C. de Bruyne . .	Les Monadines et leur place systématique. 'Bull. Soc. Belg. de Microscopie,' T. 17, 1891.
Dr. A. Russo . . .	Fasi di sviluppo del sistema acquifero e dello scheletro calcareo nell' Amphiura squamata. 'Anatom. Anzeiger,' Jgg. 6, 1891.
„ . . .	Ricerche citologiche sugli elementi seminali delle Ophiureæ, &c. 'Intern. Monatsschr. f. Anat. u. Physiol.,' Bd. 8, 1891.
„ . . .	Die Keimblätterbildung bei Amphiura squamata. 'Zool. Anz.,' Jgg. 14, 1891.
Prof. J. Rückert . .	Zur Befruchtung des Selachiereies. 'Anat. Anz.,' Jgg. 6, 1891.
Dr. F. S. Monticelli .	Di alcuni organi di tatto nei Tristomidi, Parte I. 'Boll. Soc. Nat. Napoli,' Anno 5, 1891.
„ „ . .	Osservazioni intorno ad alcune forme del Genere Apoblema Dujard. 'Atti R. Accad. Scienze,' Torino, vol. 26, 1891.
„ „ . .	Della spermatogenesi nei Trematodi. Nota riassuntiva. 'Boll. Soc. Nat. Napoli,' Anno 5, 1891.
Dr. Monticelli and Dr. Crety	Ricerche intorno alla sottofamiglia Solenophorinæ. 'Memorie R. Acc. Sc. Torino,' T. 41, 1891.
Dr. K. Fiedler . .	Entwickelungsmechanische Studien an Echinodermen-Eiern. 'Festschrift Nägeli-Kölliker,' Zürich, 1891.
Dr. O. Bürger. . .	Ueber Attractionssphären in den Zellkörpern einer Leibesflüssigkeit. 'Anat. Anz.,' Jgg. 6, 1891.
„ . .	Die Enden des excretorischen Apparates bei Nemertinen. 'Zeitschr. f. wiss. Zoologie,' Bd. 53, 1891.
„ . .	Vorl. Mittheilungen über Untersuchungen an Nemertinen des Golfes von Neapel. 'Nachr. Ges. Wiss,' Göttingen, Jgg. 1891.
Dr. P. Mingazzini . .	Gregarine Monocistidæ, nuove o poco conosciute del Golfo di Napoli. 'Rendic. R. Acc. dei Lincei,' vol. 7, 1891.
„ . .	Le Gregarine delle Oloturie. *Ibid.*
Dr. P. Cerfontaine . .	Notes préliminaires sur l'organisation et le développement de différentes formes d'Anthozoaires, 2ème communication. 'Bull. Acad. Roy. Belgique,' T. 22, 1891.
Dr. B. Rawitz. . .	Ueber Pigmentvernhiebungen im Cephalopodenange unter dem Einfluss der Dunkelheit. 'Zool. Anz.,' 1891
„ . . .	Zur Physiologie der Cephalopendenretina. 'Archiv f. Anat. u. Physiologie, Physiol. Abth.,' 1891.
Dr. C. Schneider . .	Einige histologische Befunde an Coelenteraten. 'Zool. Anz.,' 1891.
Dr. A. Coggi . . .	Le vescicole di Savi e gli organi della linea laterale nelle Torpedini. 'Rendic. Acc. Lincei,' vol. 7, 1891.
„ . . .	Sullo sviluppo delle Ampole di Lorenzini. *Ibid.*
Dr. H. L. Russell . .	Untersuch. über im Golfe von Neapel lebende Bacterien. 'Zeitschr. f. Hygiene u. Infections-Krankheiten,' Bd. 11, 1891.
Dr. M. Verworn . .	Gleichgewicht u. Otolithenorgan. Experimentelle Untersuch. 'Pflüger's Archiv,' Bd. 50, 1891.
Dr. J. Gogorza . .	Influencia del agua dulce en los animales marinos. 'Anal. de la Soc. Esp. de Hist. Nat.,' T. 20, 1891.

Dr. Kruse and Dr. Pansini	Untersuch. über den Diplococcus pneumoniæ u. verwandte Streptokokken. 'Zeitsch. f. Hygiene u. Inf.-Krkhtn.,' Bd. 11, 1891.
Dr. W. His, jun.	Die Entwickelung des Herznervensystems bei Wirbelthieren. 'Abth. math. phys. Classe Sächs. Ak. Wiss.,' Bd. 18, 1891.
Prof. Ph. Knoll	Ueber Protoplasmaarme u. Protoplasmarische Muskulatur.' 'Denkschr. Wiener Ak. M. N. Cl.,' Bd. 58, 1891.
Dr. F. Schütt	Sulla formazione scheletrica intracellulare di un Dinoflagellato. Neptunia, No. 10, 1891.
Mr. S. F. Harmer	On the Nature of the excretory processes in marine Polyzoa. 'Quart. Journ. Micr. Science,' vol. 32, 1891.
Dr. G. Mazzarelli	Note Anatomiche sulle Aplynidæ. 'Boll. Soc. Nat. Napoli,' Anno 5, 1891.
Dr. R. Zoja	Sulla trasmissibilita degli stimoli nelle colonie di Idroidi. 'Rend. R. Ist. Lombardo,' vol. 24, 1891.
„	Su alcuni esemplari di Dendroclava Dohrnii, Weismann. 'Boll. Scientif.,' Pavia, 1891.
Mr. G. Bidder	Notes on Calcareous Sponges. 'Quart. Journ. Micr. Science,' vol. 32, 1891.
Mr. H. Ward	On some points in the Anatomy and Histology of Sipunculus nudus, L. 'Bull. Mus. Comp. Zool.,' Harvard College, vol. 21, 1891.

IV. *A List of Naturalists, &c., to whom Specimens have been sent from the end of June* 1891 *to the end of June* 1892.

					Lire c.
1891.	July	3	Anatom. Inst., Christiania	Amphioxus	4·90
	„	7	Owens College, Manchester	Collection	343·20
	„	10	Zoolog. Inst., Heidelberg	Worms	15·
	„	„	Anatom. Dep., Oxford	Various	261·35
	„	15	Science and Art Mus., Dublin	Various	190·
	„	„	Mus. Municipal, Ponto Delgada	Shells	36·15
	„	16	Lab. di Patologia, Bologna	Embryos of Lacerta	6·80
	„	17	Packer College Inst., Brooklyn	Collection	240·45
	„	21	Zool. Inst., Munich	Various	68·25
	„	28	University College, London	Crustacea, &c.	88·50
	„	30	A. Manzella, Florence	Pelagia	9·70
	Aug.	14	Takata & Co., London	Collection	164·
	„	„	Museo Zool. dei Vertebrati, Florence.	Various	36·30
	Sept.	1	Zool. Institute, Bâle	Collection	313·05
	„	„	Anat. Dep., Oxford	Chætopoda	101·10
	„	2	Kunstgewerbe-Museum, Berlin	Typical forms	67·25
	„	„	Zool. Museum, Moscow	Various	115·15
	„	4	Vassar College, Poughkeepsie	Collection	310·80
	„	„	Trinity College, Cambridge	Embryos of Pristiurus	42·20
	„	10	Zool. Inst., Rostock	Collection	356·30
	„	„	Anatom. Inst., Breslau	Embryos of Mustelus	13·45
	„	11	A. Cole, Berkhamsted School	Amphioxus	6·6
	„	„	Anat. Dep., Oxford	Collection	1654·20
	„	22	Dr. B. Rawitz, Berlin	Cephalopoda	33·05
	„	„	Zool. Inst., Göttingen	Arenicola	2·40
	„	23	Zool. Inst., Zurich	Collection	388·85
	„	„	Zool. Sammlung, Zurich	Various	74·70
	„	29	Durham College of Science, Newcastle-on-Tyne.	Collection	200·
	Oct.	6	Zool. Institute, Berlin	Collection	659·15
	„	„	A. Pichler's W^we & Son, Vienna	Various	11·25
	„	13	Dr. L. Eger, Vienna	Collection	455·
	„	„	Zool. Inst., Amsterdam	Caulerpa	4·65
	„	„	Prof. A. Froriep, Tübingen	Embryos of Torpedo	24·25

					Lire c.
1891.	Oct.	16	Kreisrealschule, Munich	Collection	624·
	„	21	Oberrealschule, Sechshaus, Vienna.	Collection	89·
	„	„	J. Sinel, Jersey	Amphioxus, Corallium.	25·
	„	23	Obergymnasium, Klausenburg	Collection	219·
	„	24	Mr. G. W. Butler, Surbiton	Embryos of Elaphis	6·70
	„	30	Ateneo Galileo Galilei, Naples	Small collection	75·05
	„	„	Zootom. Cabinet, Warsaw	Various	111·75
	„	„	Gabinetto Zoologico, Perugia	Trygon	8·05
	Nov.	9	Prof. R. Bergh, Copenhagen	Pleurobranchæa Meckelii.	13·75
	„	„	Dr. P. Pelseneer, Ghent	Mollusca	12·
	„	10	Zool. Institute, Bâle	Various	51·55
	„	16	Naturw. Verein, Regensburg	Spongia	20·
	„	„	A. Pichler's W. & S., Vienna	Various	33·05
	„	„	Lab. d'Anat. Comp., Geneva	Amphioxus	22·95
	„	17	Anat. Dep., Oxford	Kophobelemnon	16·55
	„	21	Mr. W. Schlüter, Halle a/S.	Various	175·70
	„	22	Mr. J. Sinel, Jersey	Various	87·45
	„	27	Zool. Instit., Berlin	Dibotryorhynchus	3·
	„	„	Zool. Inst., Munich	Skin of Dog-fish	6·45
	„	„	Pflanzenphysiol. Inst., Munich	Calcareous Algæ	7·55
	„	„	Mr. F. H. Butler, London	Amphioxus	16·
	Dec.	1	Dr. S. Kaestner, Leipzig	Embryos of Torpedo	25·25
	„	4	K. K. Franz-Josefs Gymn., Vienna.	Collection	110·90
	„	„	Mr. G. Schneider, Bâle	Various	129·80
	„	7	Cand. A. Sokolowsky, Berlin	Heads of fishes	17·55
	„	10	Lyceum, Graz	Teredo, various	9·05
	„	11	A. Pichler's W. & S., Vienna	Corallium	17·45
	„	„	Miss J. B. Platt, Freiburg	Amphioxus	6·20
	„	16	Morphol. Lab., Cambridge	Sipunculus, Antedon, &c.	197·60
	„	„	Mr. H. Kupfer, Magdeburg	Corallium, &c.	46·05
	„	„	Dr. P. Pelseneer, Ghent	Mollusca	6·35
	„	18	University of Colorado, Boulder	Collection and Algæ	350·50
	„	19	Musée Zoologique, Lausanne	Collection	169·30
	„	„	Zoolog. Inst., Vienna	Various	49·
	„	20	Mr. J. Sinel, Jersey	Various	57·75
	„	21.	Zool. Inst., Jena	Salpa	29·10
	„	„	E. Kopperhorn, Paris	Sycandra, Pelagia	6·55
	„	„	Calderoni & Co., Budapest	Collection	290·05
	„	27	A. Pichler's W. & S., Vienna	Various	73·05
	„	31	Zool. Inst., Munich	Botryllus	9·35
1892.	Jan.	4	Mus. of Comp. Zoology, Cambridge, Mass.	Amathia Rissoana	11·40
	„	6	Dr. L. Eger, Vienna	Various	42·50
	„	12	Zool. Inst., Zurich	Various	31·40
	„	„	R. Museo dei Vertebrati, Florence.	Thalassochelys	14·
	„	14	Zool. Inst., Munich	Amphioxus	8·05
	„	„	Mr. J. Sinel, Jersey	Various	90·75
	„	18	Lab. di Fisiologia, Turin	Torpedo	10·50
	„	20	Mason Science College, Birmingham.	Collection	229·95
	„	„	Zool. Inst., Göttingen	Arenicola	3·05
	„	25	Queen's College, Belfast	Amphioxus	8·80
	„	26	Thierärztl. Hochschule, Dresden	Various	44·90
	„	28	Liceo Ginnasiale, Jesi	Collection	50·25
	„	„	Oberrealschule, Vienna	Collection	66·50
	„	30	Liceo Ginnasiale, Matera	Collection	88·75
	„	31	A. Pichler's W. & S., Vienna	Various	72·55

					Lire c.
892	Feb.	5	Zool. Inst., Greifswald	Collection	205·30
	„	6	Naturhist. Mus., Lübeck	Collection	169·30
	„	9	Agric.-chem. Lab., Zurich	Ascidia mentula, dried tests.	6·65
	„	10	Zool. Inst., Jena	Salpa	14·85
	„	„	C. L. Weitzmann, Frederiksborg	Various	75·05
	„	11	R. Scuola Sup. di Agric., Milan	Actinia	24·
	„	13	Prof. E. Herter, Berlin	Octopus	15·20
	„	„	Zool. Garten, Hamburg	Living specimens	28·50
	„	„	R. College of Surgeons of England, London	Animals showing commensalism.	98·20
	„	16	K. K. Realschule, Königgrätz	Various	27·55
	„	„	K. K. Staatsgymnasium, Königgrätz.	Various	75·50
	„	17	Mr. de Vicq, Temesvár	Material containing diatomaceæ.	12·75
	„	19	Museo Zoologico, Naples	Collection	138·40
	„	20	Museo de História Natural, Montevideo.	Collection	300·
	„	22	Mr. A. Tiedemann, Kiel	Collection	81·95
	„	27	Mr. J. Sinel, Jersey	Various	23·55
	„	28	Mr. W. Apel, Göttingen	Various	54·05
	„	„	Yale University, New Haven	Various	65·70
	March	1	Univ. College, Aberystwyth	Various	62·80
	„	4	Anat. Inst., Breslau	Embryos of Mustelus	17·45
	„	10	Zool. Inst., Zurich	Cucumaria Planci	36·95
	„	„	Zool. Museum, Helsingfors	Collection	1326·65
	„	16	Morphol. Lab., Cambridge	Amphioxus, Ciona, &c.	168·85
	„	22	Mr. V. Frič, Prague	Argonauta, Rhizostoma	95·40
	„	„	Mr. E. Bonomi, Milan	Various	11·15
	„	„	Prof. A. Froriep, Tübingen	Embryos of Torpedo	10·10
	April	2	University Coll., London	Various	13·10
	„	3	Mr. F. Heydrich, Langenselza	Algæ	4·75
	„	„	Thierärztl. Hochschule, Munich	Pristiurus	12·65
	„	7	Balfour Lab., Cambridge	Collection	67·05
	„	9	Realgymnasium, Sprottau	Collection	70·80
	„	10	Mr. J. Sinel, Jersey	Various	44·
	„	12	Dr. H. Klaatsch, Heidelberg	Amphioxus	3·15
	„	„	Lab. de Zoologie, Lausanne	Amphioxus, Petromyzon	17·65
	„	„	Lab. d'Embryogénie Comp., Paris	Thalassicolla	1·75
	„	15	Physiol. Inst., Utrecht	Embryos of Torpedo	36·15
	„	16	Fac. des Sciences, Lyon	Collection	146·60
	„	21	Musée d'Hist. Nat., Geneva	Various	12·10
	„	„	Eimer and Amend, New York	Amphioxus	104·90
	„	„	Dr. E. C. Bousfield, London	Oikopleura	3·45
	„	22	Université, Geneva	Various	10·50
	„	26	Durham Coll. of Science, Newcastle-on-Tyne.	Amphioxus	14·
	„	28	Columbia College, New York	Collection	1367·15
	„	„	Zool. Garten, Hamburg	Living specimens	17·50
	May	4	Zool. Inst., Bonn	Various	87·75
	„	7	Gumpendorfer Oberrealschule, Vienna.	Collection	143·60
	„	„	Station biologique, Sebastopol	Shells	48·65
	„	12	Musée Zool., Moscow	Collection	231·25
	„	„	A. Pichler's W. & S., Vienna	Various	50·60
	„	„	Mus. of Comp. Zoology, Cambridge, Mass.	Siphonoceros	3·15
	„	„	Thierärztl. Hochschule, Munich	Pristiurus	7·
	„	14	Mr. S. Brogi, Siena	Various	47·30
	„	16	Zool. Inst., Königsberg	Various	27·
	„	19	Naturhist. Museum, Hamburg	Various	93·30

					Lire c.
1892.	May	20	Liceo Ginnasiale, Jesi	Various	67·45
	„	„	Staatsgymnasium, Oberhollabrunn.	Collection	100·
	„	21	Zool. Dep., Edinburgh	Various	24·65
	„	„	Zool. Inst., Munich	Rhopalonema	5·
	„	„	Zool. Lab., Zurich	Amphioxus	15·65
	„	25	Anat. Dep., Oxford	Nereis	5·90
	„	„	Univ. College, Dundee	Collection	62·75
	„	„	Ministerio de Marina, Madrid	Collection	300·
	„	31	Liceo Umberto I., Naples	Small collection	40·
	„	„	R. Ist. di Stud. Sup., Florence	Living specimens	12·05
	„	„	Zool. Inst., Heidelberg	Auftrieb, various	90·65
	June	6	Lab. de Zool., Lyon	Balanus, Scalpellum	8·85
	„	„	Dr. P. Pelseneer, Ghent	Mollusca	7·20
	„	„	Realgymnasium, Posen	Various	30·35
	„	17	Anat. Dep., Oxford	Collection	380·30
	„	„	Lab. di Clinica med., Bologna	Embryos of Torpedo	12·
	„	„	R. Museo Zool., Bologna	Embryos of Torpedo	11·20
	„	„	Mr. S. Brogi, Siena	Various	12·70
	„	21	Museo Zool., Catania	Embryos of Torpedo	19·40
	„	„	Zool. Dep., Edinburgh	Embryos of Torpedo	19·
	„	„	Prof. Ciaccio, Bologna	Embryos of Torpedo	26·85
	„	„	Faculté des Sc., Nancy	Synapta	4·75
	„	27	A. Pichler's W. & S., Vienna	Various	24·10
	„	„	Zool. Inst., Strasburg	Ephyra of Pelagia	2·80
					17,413·05

Fifth Report of the Committee, consisting of Dr. P. L. Sclater (*Chairman*), Mr. George Murray (*Secretary*), Mr. W. Carruthers, Dr. A. C. L. G. Günther, Dr. D. Sharp, Mr. F. DuCane Godman, Professor A. Newton, *and* Dr. D. H. Scott, *appointed for the purpose of reporting on the present state of our knowledge of the Zoology and Botany of the West India Islands, and taking steps to investigate ascertained deficiencies in the Fauna and Flora.*

This committee was appointed in 1887, and it has been reappointed each year until the present time.

Zoology.

Of the naturalists mentioned in the last report as having undertaken the working out of groups, Lord Walsingham has published his account of the Microlepidoptera of the West Indies in the 'Proceedings of the Zoological Society.' M. Simon has contributed to the same journal Part I. of his paper 'On the Spiders of the Island of St. Vincent,' and Herr Hofrath Brunner v. Wattenwyl has in the same place published his 'Memoir on the Orthoptera.' Interim reports as to progress have been received from the others. Mr. Peckham has postponed his paper on the Attidæ until his return from the West Indies, since he anticipates large additions to his knowledge of this part of the fauna of the islands. Mr. R. I. Pocock has undertaken the working out of the myriapods, scorpions,

and freshwater crustacea, and his memoir is in an advanced state of preparation. It will include those of St. Vincent and Grenada, and it may be recalled that he has already worked out those groups from Dominica.

At the time of the last report Mr. Herbert H. Smith, the collector employed by Mr. Godman, was engaged in making collections in zoology in the island of Grenada. This collection has now been received in this country, and great part of it mounted under the direction of Dr. Sharp. From this island there are in his custody of mounted Coleoptera 16,700 specimens, of mounted Hymenoptera 1,380 specimens, of mounted Hemiptera 1,215 specimens, of Hemiptera in spirit 400 specimens, of Ants in spirit about 600 specimens, of mounted Orthoptera 100 specimens—in all 20,395 specimens. From the same island, and in the custody of Mr. Godman, there are (all of them mounted) of Diptera about 2,620 specimens, of Homoptera 380 specimens, of Hemiptera 1,195 specimens, of Neuroptera 112 specimens, of Orthoptera 100 specimens, of Hymenoptera 227 specimens, of Lepidoptera 860 specimens—in all 25,889 specimens from this island—besides collections of land-shells, snakes, scorpions, myriapods, arachnida in spirit, &c., not yet examined.

A small collection of birds made by Mr. Elliott during his visit to Anguilla (referred to below) has been received and named by Dr. Sclater. A list of the species will be published in the 'Proceedings of the Zoological Society.'

Botany.

A paper by Mr. J. G. Baker 'On the Vascular Cryptogamia of the Island of Grenada,' based on the collections made by Mr. R. V. Sherring, who was sent to Grenada by the Committee during the winter of 1890–91, has appeared in the 'Annals of Botany,' April, 1892. Among the orchids collected by Mr. Sherring and named at Kew there are a number of additions to the flora and several possible new species.

So little result in the way of novelty or additions to our knowledge of distribution appeared to follow the explorations of the Committee in the matter of vascular plants that it was determined to devote attention especially to the cellular cryptogams, of most branches of which an imperfect record existed. Mr. W. R. Elliott was accordingly sent to St. Vincent for a period of six months to collect cellular cryptogams, and with instructions to visit the little known island of Anguilla. Mr. Elliott has sent home extensive collections (nearly 1,000 numbers altogether, each well represented) from both islands, and they are now being worked out at the British Museum. A small collection of flowering plants from Anguilla which accompanied these possesses little interest. The fungi have been already described in part by Mr. George Massee in a paper in the 'Journal of Botany,' and twenty species of this group new to science have thus far been discovered and here recorded. Mr. Antony Gepp has undertaken to work out the Musci and Hepaticæ, of which an extensive series has been collected; and Mr. George Murray has undertaken the Algæ, from which group comparatively few novelties are expected, since he has recently catalogued the marine Algæ of this region. The Lichenes have not been allotted. Mr. Elliott, having finished this part of his work, viz., St. Vincent, has proceeded to Dominica, an island from which a larger number of new records may be confidently anticipated, since it is

much less cultivated, is covered with dense forest, and possesses a greater range in elevation.

The Committee recommend their reappointment with the following members:—Dr. Sclater (Chairman), Mr. George Murray (Secretary), Mr. Carruthers, Professor Newton, Mr. Godman, Dr. Günther, Dr. Sharp, Dr. Scott, and Colonel Feilden. The Committee also recommend that a grant of 200*l.* be placed at their disposal for the continuation of their work.

Second Report of the Committee, consisting of Professor A. Newton (*Chairman*), Dr. W. T. Blanford, Dr. S. J. Hickson, Professor Riley, Mr. O. Salvin, Dr. P. L. Sclater, Mr. E. A. Smith, *and* Mr. D. Sharp (*Secretary*), *appointed to report on the present state of our knowledge of the Zoology of the Sandwich Islands, and to take steps to investigate ascertained deficiencies in the Fauna, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government.*

Your committee met that appointed by the Royal Society, and a joint committee was formed, with Professor Newton as Chairman, Dr. Hickson, Treasurer, and Mr. D. Sharp, Secretary. The joint committee decided to send out a competent collector to the islands, and finally selected, from among several candidates who presented themselves, Mr. R. C. L. Perkins, B.A., of Jesus College, Oxford.

Mr. Perkins left England in February last, and reached Honolulu in March. Letters received from him since then give assurance that he is sparing no effort to carry out successfully the task with which he has been entrusted, and a case containing the material results of his first two months' work in Oahu is now on its way to England by sea, its transmission by the nearest route being considered inexpedient.

The Committee have left considerable discretion to Mr. Perkins in regard to his operations in the islands, and it being evident that the birds and some groups of molluscs are those which chiefly attract the amateur collector, he has rather devoted his attention to the rest of the fauna, which unless taken in hand by some body, such as this committee, would probably not be investigated at all. At the same time, Mr. Perkins has been directed to pay attention to certain points in Ornithology and Malacology which require elucidation, and the Committee are confident that he will not neglect them. To attend to these points in Ornithology, to collect the Mollusca with special attention to their local range, and to make as complete a collection as may be possible of the other invertebrate fauna will, the Committee consider, occupy Mr. Perkins for fully two years.

The Committee have no reason to think that Mr. Perkins is incurring any unnecessary expenses; but the cost of living and travelling in the islands is very considerable, and, in order to retain that gentleman's services so as to complete the task in the way the Committee think de-

sirable, additional funds must be found. The Committee therefore request that they may be reappointed with the same powers as before, and that the sum of 200*l.* be placed at their disposal.

Report of the Committee, consisting of Professor RAY LANKESTER (*Chairman*), Professor M. FOSTER, Professor S. H. VINES, *and* Mr. S. F. HARMER (*Secretary*), *appointed for the purpose of arranging for the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth.*

THE amount of the grant placed at the disposal of the Committee for the present year was 17*l.* 10*s.*, being the unexpended balance of the grant of the previous year.

The Committee have received four applications for the use of a table, but their funds have not allowed them to make more than three nominations, of which one was for a shorter period than was asked for.

They have nominated—

Mr. F. W. Gamble, B.Sc., of Owens College, Manchester, for two months from August 1, 1892.

Mr. Edgar J. Allen, of University College, London, for six weeks from June 3, 1892.

Mr. Gregg Wilson, M.A., B.Sc., Assistant to the Professor of Natural History at the University of Edinburgh, for one month from August 15, 1892.

As has been the case on previous occasions, the Committee have included in the above periods the month which belongs to the Association free of charge.

Mr. Gamble proposes to work at the Turbellarian Fauna of Plymouth Sound and its neighbourhood. Mr. Allen, who is already at Plymouth, intends to use his time there for the study of the development of Decapod Crustacea. Mr. Gregg Wilson proposes to investigate the Food of Fishes.

The Committee expressed the hope in their last report that they would be able to give in their report for this year some account of the results arrived at by the persons who were appointed with the assistance of the grant made at the meeting of the Association in 1890. As these appointments fell within the months July–September 1891 it was obviously impossible to incorporate their results in the last report. The Committee are glad to be in a position to furnish the following information with regard to the results of their expenditure of 12*l.* 10*s.* of the previous grant:—

I. *Report on the Occupation of the Table.*
By Miss FLORENCE BUCHANAN, *B.Sc.*

Last year, owing to the kindness of the British Association, I was enabled to spend the month of July at the Marine Biological Laboratory at Plymouth. I went down intending to work at some points in the

anatomy of Polychæt worms, and to determine the amount of value to be attached to chætæ and parapodia of homologous segments as a means of classification. I found, however, that I must begin by identifying the different forms occurring at Plymouth, as very little work had been done there on Polychæts up to that time. Seeing that every Polychæt has, on the average, a good many more than half a dozen names, and that each name belongs to about half a dozen different Polychæts, this is no very easy task, and it has occupied me, on and off, since my return from Plymouth in the Zoological Laboratory of University College, London, and I am afraid is not yet complete. I obtained, altogether, over a hundred different species, some of them found, I believe, for the first time on our coast, and a few which seem to be new altogether. With regard to the collection of them, I have to thank my fellow-workers in the laboratory, and especially Mr. Garstang, for much help given me. I must also thank Mr. Cunningham for notes and drawings of some of the Plymouth Polychæts found there up to that time, which he kindly placed at my disposal. With regard to the naming of them, I have received a good deal of assistance from an incomplete and as yet unpublished 'Synonymous List of Polychæt Worms,' by Professor Haddon, which he has kindly put into my hands for revision and completion.

The most interesting of the new forms obtained is a small Eunicid, resembling the genus *Ophryotrocha* of Claparède and Metschnikoff ('Z. f. w. Z.' XIX. p. 184, Pl. XIII. fig. 2) in having the larval ciliated bands persistent in the adult. The shape of the jaws and parapodia (which I propose to figure in giving a full account of this small worm elsewhere), the possession of two pairs of prostomial tentacles instead of only one, and these both provided with stiff hairs not only in the young stages but in the adult, seem to me, however, to mark it off as a distinct genus, although certainly more nearly allied to *Ophryotrocha* than to any other known Annelid. There is a ciliated band on the prostomium, and one on each of the following segments. All the segments after the first two (and the last two or three in small specimens) have well-developed parapodia, each consisting of a chætigerous lobe containing both simple and compound chætæ, and a small cirrus. In the body-cavity and in the parapodia of most of the specimens eggs are to be found, which, curiously enough, like those of *Ophryotrocha*, are generally double, consisting, namely, of a large granular part, of a yellowish-brown colour, containing (in this case, but evidently not in the eggs of *Ophryotrocha*) the nucleus, and a smaller colourless part (containing the nucleus in eggs of *Ophryotrocha*) which stains very deeply with carmine. Whether this smaller part represents a polar body or not remains to be determined. Sections show that at least one pair of excretory organs is present in the shape of small tubes blocked up by yellow concretions lying in the second and third segments and (?) opening at the side of the second to the exterior.

The only other form amongst those I have as yet examined which may rank as a new genus is a member of the family Ampharetea, differing from *Samytha* and *Amage* especially in having a large number of segments (at least thirty-seven) with uncinigerous pinnules behind those with bundles of capillary setæ. It would either form a new genus with the *Samytha pallescens* of Theel ('Kongl. Sv. Vet. Ak. Handlingar,' Bd. XVI.), which he places doubtfully as a *Samytha*, or the genus *Samytha* must be enlarged

to include, not only both these forms, but the genus *Amage* as well; or even both these genera might be swallowed up in the still older genus *Sabellides*.

The other forms I collected at Plymouth I will here only just briefly enumerate in so far as I have at present identified them, leaving any remarks I may have to make on them for publication in the 'M.B.A. Journal,' to which the director has asked me to contribute by degrees an annotated catalogue of the Polychæts occurring near Plymouth. Although I have several specimens of species belonging to the families *Polynoidea*, *Lycoridea*, and *Serpulacea*, I have at present identified so very few of them, except the quite common ones, that I think it best to omit them altogether in the following list. I will mark with an asterisk those forms which I believe not to have been found on the British coast before. A '?' attached to a name signifies either that, after examination, I am not quite satisfied with the identity of the specimen in my possession with the name I have given it, or that the specimen was not complete enough for specific characters to be determined.

Fam. Amphinomea . .	Euphrosyne foliosa, Aud. and Edw.
Fam. Aphroditea . .	Aphrodite aculeata, L.
	* „ obtecta, Ehl. (?).
	Hermione hystrix, Sav.
Fam. Eunicea; Sub-fam.	
Labidognatha . . .	Hyalinœcia tubicola (Müll.), Mgrn.
	Lysidice ninetta, Aud. and Edw.
	Nematonereis unicornis, Schm.
Prionognatha . . .	Lumbriconereis tricolor, Johnst.
	„ gracilis, Ehl.
	**Ophryotrocha-like genus*—new.
Fam. Nephthydea . .	Nephthys cœca, Fabr.
Fam. Glycerea . . .	Glycera capitata, Oerst.
Fam. Syllidea . . .	Syllis prolifera, Krohn (*asexual and sexual* ♀).
	Syllis cornuta, Rthke. (*asexual and sexual* ♀).
	„ armillaris, Oerst. (?).
	Syllis (Eusyllis) lamelligera, Mar. and Bobr. (?).
	*Syllis, n. sp. (?).
	Amblyosyllis (Gattiola, Johnst.) spectabilis, Johnst.
	Exogone naidina, Oerst. (with laterally attached young).
	*Sylline brevipes, Clp. (?).
	Autolytus prolifer (Müll.), Gr. ♂.
Fam. Nerillidæ . . .	*Nerilla antennata (Schmidt), Clp.
Fam. Hesionea . . .	Castalia (Psammathe, Johnst.) punctata, Müll.
	Castalia arctica, Mgrn.
	*Magalia (Mar. and Bobr.), n. sp.
Fam. Phyllodocea . .	Phyllodoce lamelligera, Johnst.
	„ maculata, Müll. and Johnst.
	Eulalia viridis (Sav.), Oerst.

Fam. Phyllodocea . .	Eulalia bilineata, Johnst.	
	,, punctifera, Gr. (?).	
	or	
	,, Griffithsii, Johnst.	Some of these may be new.
	,, flava, Oerst. (?).	
	,, problema, Mgrn. (?)	
	* ,, lobocephela, Schm. (?).	
	Notophyllum polynoides, Oerst.	
	Genetyllis lutea, Mgrn.	
	*Mysta (Mgrn.), n. sp.	
	Eteone picta, Qfg.	
Fam. Arenicolidæ . .	Arenicola marina, L.	
	,, ecaudata, Johnst.	
Fam. Spiodea . . .	Leucodore ciliatus, Johnst.	
	Scolecolepis vulgaris, Johnst.	
	Nerine coniocephela, Johnst. (?).	
Fam. Magelonidea . .	Magelona (*larva in two stages*).	
Fam. Chætopterida . .	Chætopterus insignis, Baird.	
Fam. Cirratulida . .	Dodecaceria concharum, Oerst.	
	Chætozone, sp. (?).	
	Cirratulus borealis, Lam.	
Fam. Terebellacea; Subfam. Amphitritea . .	Leprea lapidaria (L.), v. Mrzllr. (include L. textrix, Mgrn.).	
	Lanice conchilega (Pall.), Mgrn.	
	Nicolea zostericola, Mgrn., *and young*.	
	Polymnia nebulosa (Mont.), v. Mrzllr.	
	Thelepus circinnatus (Fabr.), v. Mrzllr.	
	,, sp. (?).	
	Pista cristata (Müll.), Mgrn.	
	*Pista (?), n. sp. (or possibly new genus).	
Polycirridæ . .	Polycirrus aurantiacus, Gr.	
	* ,, (Aphlebina) hematodes, Clp.	
	* ,, ,, pallidus, Clp.	
Fam. Ampharetea . .	Amphicteis Gunneri, Sars.	
	*Sabellides, n. sp. (?).	
	*Samytha (?), n. sp. (or new genus).	
Fam. Amphictenea . .	Pectinaria belgica, Pall.	
Fam. Pherusea . .	Siphonostoma diplochætos, Otto.	
Fam. Hermellacea . .	Sabellaria alveolata, Lam.	

Although I am otherwise leaving the family Serpulacea unmentioned, I will just note that belonging to the tribe Amphicoridæ I found not only several specimens of *Fabricia*, but also two of *Haplobranchus* (A. G. Bourne), hitherto only known to occur at the mouth of the Thames. These were found in tide-pools not far from the mouth of the Yealm.

With regard to the second object of my visit to Plymouth, namely, to find out how great or how little is the range of variation in homologous parapodia, I collected whilst there a large number of specimens of the only Polychæt obtainable in any great abundance, namely, *Nereis diversicolor*, and have begun making camera drawings of parapodia of certain segments in each specimen.

Of course a list of specimens collected during a month's stay at Plymouth cannot be taken as by any means a complete list of forms occurring there, and, while expressing my thanks to the British Association for so kindly allowing me the use of its table last year, I should like at the same time to express the hope that on some future occasion it will enable me to continue the work, and, having got over the drudgery of mere labelling, to pass on to some of the many interesting morphological problems connected with Polychæts which remain to be worked out.

II. *Report on the Occupation of the Table. Some preliminary notes on the anatomy and habits of* Alcyonium digitatum. *By* Mr. Sydney J. Hickson, *M.A., Fellow of Downing College, Cambridge.*

Alcyonium digitatum is one of the most difficult Cœlenterates to kill in a fully expanded condition. In the first place it is only extremely rarely that the large proportion of the polypes of a specimen in an aquarium fully expand themselves, and when they are in that condition the slightest touch or irritation of any part of the colony causes an immediate contraction of the tentacles. Again, when a favourable opportunity arises it is found that all the neutral killing reagents, such as corrosive sublimate, &c., fail to kill the polypes before they have time to partially retract. The only method that gives tolerably satisfactory results is Lo Bianco's No. II. chromo-acetic acid method, and this of course partially dissolves the calcareous spicules.

When a living specimen of an *Alcyonium digitatum* is examined in an aquarium the polypes may frequently be observed in various stages of expansion and retraction. Sometimes all the polypes are completely retracted, but I have never yet observed in any specimen all the polypes fully expanded at the same time. By far the most frequent condition of the *Alcyonium* is one in which a few polypes here and there are fully expanded; others expanded but with their tentacles contracted, and others only just protruding from the surface of the colony.

These two stages are the normal ones that each polype passes through in reaching complete retraction from complete expansion. When the polype is completely expanded both the body-wall and the tentacles are delicate and transparent.

The first stage in the retraction is the contraction of the tentacles. The crown of the polype becomes roughly octagonal in shape with an obtuse solid knob, the contracted tentacle, at each angle.

In the next stage the contracted tentacles bend over towards the mouth, and concurrently with the retraction of the body of the polype they sink into a circular fold of the body-wall.

The invagination of the polype then proceeds at the base until the crown covered by the fold of body-wall sinks below the surface of the colony.

When the crown has sunk below the surface of the colony the aperture is closed by the folding of the delicate body-wall of the base of the polype over the crown; but when the colony enters into a state of complete contraction, as it does, for example, when it is taken out of the water for a few minutes, the tough obtuse surface of the colony contracts over this delicate base, leaving only a star-like slit to mark the position of the retracted polype.

The ectoderm is in the uninjured specimens composed of several layers of cells. Under unhealthy conditions the superficial layers are apt to slough.

The stomodæum of each fully-developed polype opens into a long cœlenteron that passes down to the base of the colony. In a longitudinal section through a branch of the colony the cœlentera spread from the base in a fan-like manner towards the periphery.

Between the cœlentera there is a dense, clear mesogloea containing spicules, endodermic cell-cords, a very delicate network of nerve (?) fibrils and cells.

The young polypes originate in these endodermic cords, the cœlentera being developed later, and do not communicate directly with the cœlentera of the older polypes until they are nearly full grown.

The endodermic cords are usually described as canals, but there is no evidence of the presence of a lumen. Numerous injection experiments failed to prove the existence of any cavity in these structures.

The nerve (?) network can only be made out in fresh osmic acid preparations. It consists of a fine network of delicate fibrils connecting isolated mono-, bi-, and tri-polar cells. It is difficult to trace in the peripheral parts of the colony, the presence of a very large number of spicules making it very difficult to cut thin sections of the fresh tissues.

When the tide is low in the tropics some forms of Zoophytes, such as *Tubipora*, *Clavularia*, *Sarcophytum*, the Astræidæ, and a few others, remain expanded until the water actually leaves the reefs. Others, on the other hand, such as *Heliopora*, *Millepora*, and most of the Madrepores, completely retract while there is still a foot or more of water covering them. Some zoophytes, in fact, appear to anticipate low tide before others, and it occurred to me that this might be due, to a certain extent, to the development of a rhythm similar to the rhythmic movements of certain plants.

In order to determine, if possible, the truth or falsity of this supposition I made last autumn a series of experiments upon *Alcyonium digitatum* in the tanks at the Plymouth Laboratory.

I placed a number of specimens of *Alcyonium digitatum*, collected partly in the shallow water of the Catwater and partly in deeper water off the Eddystone Lighthouse, in one of the tanks, and I noticed that nearly all of them contracted completely twice in every twenty-four hours for the first three or four days.

Those that did not contract in this manner soon showed bubbles of gas in their tissues and commenced to putrefy.

I also placed a number of specimens in another tank in which I arranged an artificial tide by means of syphons. It was so arranged that the water should run off—but not so completely as to leave the Alcyoniums uncovered—in twelve hours and fill up again in twelve hours. The Alcyoniums contracted with tolerable regularity twice in twenty-four hours for the first two days, and then contracted quite irregularly, some only once, some twice. At the end of a fortnight two out of the three that remained in a healthy condition contracted regularly only once in twenty-four hours.

These experiments appear to indicate, first, that there is a rhythmic contraction of the polypes of *Alcyonium digitatum* in the normal conditions twice in every twenty-four hours; second, that a new rhythm may

be induced by an artificial tide of different duration to the natural one.

On the other hand, the results of the investigation are not altogether satisfactory, on account of, first, the large number of specimens that became unhealthy during the progress of the experiment; second, the fact that the only three specimens that survived in the tank with the artificial tide were taken from the deep water off the Eddystone.

Far more satisfactory results would probably be obtained if experiments were tried upon a number of Alcyoniums taken from shallow water direct and placed in the tanks. Many of the specimens collected from the Catwater were probably taken by the trawlers from deep water and thrown overboard as they entered the harbour, and were in consequence in an unhealthy condition when collected.

The subject, however, seems to me to be worthy of further investigation.

III. *Report on the Occupation of the Table.* *By* Mr. Arthur Willey.

I spent six weeks in the laboratory at Plymouth during the months of August and September 1891.

I was at first engaged in the study of a new genus of compound ascidians from Japan, belonging to the family of the Didemnidæ, and have already published a short description of it, in conjunction with my friend Mr. Asajiro Oka, in the 'Quarterly Journal of Microscopical Science' for January 1892.

I also made observations on the tadpoles of *Styela grossularia*, and of another small red and white Ascidian which lives on shells and stones at the bottom of the Sound, and occurs in mulberry-like masses, and which I take to be *Polycarpa glomerata*. In these forms the embryonic development up to the stage of the free-swimming tadpole takes place in the peribranchial chamber, a portion of which is converted into a special brood pouch traversed by vascular trabeculæ. The tadpoles of these Ascidians are remarkable for possessing a complete ring of hollow ectodermic tentacle-like processes which surrounds the anterior portion of the larva, at the extremity of which are borne the three adhering papillæ. The mouth is not enclosed by this ring of tentacles, but lies outside it. Similar tentacles occur in the tadpoles of the Botryllidæ and the Didemnidæ.

Their presence in Simple Ascidians is rather extraordinary, and seems to occur in correlation with the fact, already mentioned, that in these particular Simple Ascidians, by way of an exception, the development up to the tadpole stage takes place in the body of the parent. The large quantity of yolk which renders the eggs and larvæ of these forms so opaque must also be brought into relation with the mode of development. It seems to be a general rule that in the Simple Ascidians the embryonic development is a pelagic one, while in the Compound Ascidians the development takes place in some part or other of the parent colony. To this rule, of course, the two species of Simple Ascidians mentioned above form exceptions.

In the living tadpole blood can be seen flowing into the tentacles. They are capable of distension and contraction according to the degree of turgidity in which they are kept by the blood inside them. Their actual function is at present that of accessory adhering organs. When

the larva fixes itself in the usual way by the three adhering papillæ, the whole anterior portion of the body becomes drawn in or introverted, and the body of the larva presents an antero-posteriorly flattened appearance with a cup-shaped depression in front, round which the tentacles project and attach themselves by their free extremities to the surface to which the larva has fixed itself, which may be a rock or another Ascidian of the same species. I have referred to these tentacle-like processes in the paper quoted above, and have there figured a larva with a dozen tentacles. They have nothing to do with budding either actually or primitively in any Ascidian.

I also made some experiments on the larvæ of *Styela grossularia*, in which I succeeded in very sensibly hastening the change of form (*i.e.*, flattening of the body of the larva) which takes place during the metamorphosis, by cutting off the tails of the larvæ. I should say that the actual fixation of the larva is not an indispensable preliminary to the commencement of the metamorphosis, the most obvious accompaniments of which are the abovementioned flattening of the body and the absorption of the tail of the larva. By keeping a series of normal larvæ in one dish, and a series of larvæ with docked tails in another dish at the same time, I was able to compare the rate of change of shape in the two cases, and the difference was most striking.

The work which I commenced at the laboratory of the Marine Biological Association at Plymouth was continued at the Zoological Station at Naples, where I also had the privilege of occupying the table of the British Association, and the results of my work there will be given in another report.

The Committee venture to hope that the Association will again place in their hands a grant of 30*l.*, or of any smaller sum, to enable them to continue to nominate workers at the Plymouth Laboratory. They believe that the utility of the grant is becoming more widely appreciated, and they feel that the grant has been well and usefully employed. They desire to point out that, even if they should not be reappointed, the Association should make some permanent provision for nominating a worker for one month in every year; a privilege which belongs to the Association, free of charge, by virtue of its position as a Governor of the Marine Biological Association.

Sixth Report of the Committee, consisting of Professor M. Foster (*Chairman*), Professor F. O. Bower (*Secretary*), Professor I. Bayley Balfour, Mr. W. T. Thiselton-Dyer, Dr. H. Trimen, Professor Marshall Ward, Mr. W. Carruthers, Professor M. M. Hartog, *and* Mr. W. Gardiner, *for taking steps to establish a Botanical Laboratory at Peradeniya, Ceylon.*

The Committee report that, no grant having been asked for at the meeting at Cardiff, no accounts have to be rendered.

Professor J. Bretland Farmer has in the course of the year returned, after spending five months in Ceylon, and has brought back with him

large collections of material for further work. He has sent to the Committee a report, which is appended:—

The Committee, having at present before them no application for use of the laboratory, do not propose to ask for a grant this year. But as the Committee are informed that an application will be made, they request that they be reappointed, with Professor Farmer as secretary.

APPENDIX I.

Report by Professor J. Bretland Farmer.

In December 1890 I left England for Ceylon, having received from the Grant Committee of the British Association the sum of 50*l.*, to be expended in apparatus and fittings for the laboratory at Peradeniya. The chief pieces of apparatus consisted of a $\frac{1}{2}$-plate camera by Watson, a large Zeiss dissecting microscope and lenses, and a large and sensitive balance. In addition to these I further took a small supply of glass apparatus and chemical reagents.

On my arrival at Peradeniya in January 1891 I proceeded to make arrangements for storing the apparatus, &c., which I had brought, and also to make a catalogue of the existing apparatus and fittings at present available in the laboratory.

Through the kindness of the Director of the Gardens I was enabled to fit up a spare room as a photographic dark room.

For the guidance of those who may in future visit the laboratory with the intention of working there, I would suggest that it will probably be necessary to take out such glass apparatus and bottles as they may require, since, owing to the action of the climate, articles made of ordinary glass soon become corroded, appearing as if they had been exposed to the action of hydrofluoric acid.

During my visit to Ceylon I made the laboratory my working head-quarters, sorting and preserving my collections there in the intervals between various expeditions. I paid especial attention to the Hepaticæ, and for the purpose of securing as many as possible of these plants I travelled over a considerable part of the country, especially the hilly districts. I hope shortly to be able to publish some of my observations on the material thus gathered, which includes, besides some probably new species, several little known and interesting forms.

I also obtained a quantity of material for working out the development and structure of several species of the genus Christisonia, which occurs as a parasite on the Strobilanths and various species of Bamboo.

I was fortunate enough, after repeated search, to obtain prothallia and embryos of *Angiopteris evecta*, and thus to study the development of at least one member of a group of ferns concerning whose embryology we possess at present no information. These results are in course of publication in the 'Proceedings of the Royal Society,' and *in extenso* in the 'Annals of Botany.'

Besides the abovementioned instances I collected a considerable quantity of material of a varied kind, some of which has been already worked out in the Peradeniya Laboratory. Amongst this material I may mention a Podostemon, which appears to be a new form, and one of some interest.

I cannot conclude this outline report of my work in Ceylon without expressing my sense of the great kindness which I received at the hands of Dr. Trimen, the Director of the Gardens: without this help I should have been able to take but a small advantage, comparatively speaking, of the great opportunities I enjoyed during the few months I spent in the tropics.

APPENDIX II.

List of Apparatus and Reagents at Laboratory, Royal Garden, Peradeniya, Ceylon.

1 large balance with weights.
1 small ditto.
1 camera, lens, &c.
1 Zeiss dissecting microscope, aplanatic lenses, and combination lenses.
5 glass measures of 1,000, 500, 250, 100, 50 c.c. respectively.
Glass jars with covers

six	15 in. × 3½ in.	*twelve*	8 in. × 3½ in.
twelve	12 in. × 4¾ in.	*eight*	5 in. × 4¼ in.

Bell glasses

three	12 in. × 12 in.		
six	8 in. × 8 in.	*six*	6 in. × 4¾ in.

8 assorted funnels and box of cut filter papers.
About 140 wide-mouth stoppered bottles, from 600 c.c.—60 c.c.
2 Wedgwood mortars.
2 spirit lamps.
2 large nests of beakers.
Several nests of test tubes.
1 nest of 7 flat beakers and covers (5¾ in. × 3½ in.).
About 1½ gross specimen tubes, thick glass.
6½-plate porcelain photo dishes.
3 tripods and gauge.
1 copper still, tin worm (wants repairing).
8 graduated pipettes and burettes.
4 dozen watch glasses.
About 2 dozen glass capsules and covers (2 in.—3 in. diam.).
3 hydrometers 700—2,000.
1 thermometer—15° C. =370° C.
1 „ 0° C. =100° C.
1 alcoholometer.
Set of brass cork borers.
Assorted test-tube holders and brushes
„ corks and Δ files.
2 test-tube stands.

Reagents.

3 bottles potass. hyd.
2 „ chromic acid.
1 calc. chloride.
1 chloroform.
2 glycerine (large).
3 iodine.
2 potass. iodide.
1 potass. bichrom.
1 picric acid.
1 tin vaseline.
1 thymol.
1 chloral hyd.
1 oil of cloves.
2 acetic acid.
1 hæmatoxylin.
1 asphalt varnish.
1 gold size.
2 creasote.
Several small bottles of mineral acids (of little use).
1 eosin.
1 gentian violet.
1 methylene blue.

Report of a Committee, consisting of Professor A. NEWTON (*Chairman*), Mr. JOHN CORDEAUX (*Secretary*), Messrs. R. M. BARRINGTON, JOHN A. HARVIE-BROWN, W. EAGLE CLARKE, *and the* Rev. E. P. KNUBLEY, *appointed to make a digest of the observations on the Migration of Birds at Lighthouses and Light-vessels, and to report on the same.*

THE Committee are not yet in a position to announce the completion of the digest of the migration returns, with which, however, great and satisfactory progress has been made during the past twelve months by Mr. W. Eagle Clarke, one of their body, on the plan announced in last year's report. So much having been done, they trust that the Association will think fit to reappoint them in order that the heavy task may eventually be completed.

Report of the Committee, consisting of Professor A. C. HADDON, Professor W. A. HERDMAN, *and* Mr. W. E. HOYLE (*Secretary*), *appointed for improving and experimenting with a Deep-sea Tow-net for opening and closing under water.*

THE Committee have to report that the apparatus for opening and closing the tow-net by electricity, which was provisionally exhibited in an unfinished state at Cardiff, has been completed and is ready for use so soon as an opportunity for experimenting in deep water shall present itself. Although the Committee have made inquiries in all directions that seemed likely, no such opportunity has presented itself during the past twelve months. Seeing that the kind of conducting cable which would be necessary for working the apparatus would depend upon the nature of the dynamo available for generating the electric current, the Committee have not judged it prudent to expend the grant in the purchase of such a cable prematurely, and hence the grant has been returned to the Treasurer.

The Committee suggest that they should be reappointed; they intend to apply for a new grant at some future date.

Report of the Committee, consisting of Mr. THOMAS H. THOMAS (*Chairman*), Professors W. NEWTON PARKER, A. NEWTON, *and* A. LEIPNER, Mr. E. POULTON, Canon H. B. TRISTRAM, *and* Dr. C. T. VACHELL (*Secretary*), *appointed to consider proposals for the Legislative Protection of Wild Birds' Eggs.*

THE Committee have to report that in consequence of the near approach of a General Election, it seemed to them quite useless to take any further steps during the present Session of Parliament, as no Bill of the kind

could possibly pass both Houses. It also became evident, upon full examination, that the Bill introduced by Mr. Alfred E. Pease in 1891, which was suggested as a basis of action by the Committee, would, although its principle was in agreement with the object for which the Committee was appointed, nevertheless need to be considerably modified before it could satisfy the Committee.

Under these circumstances the Committee ask to be reappointed, in order that they may endeavour to secure the introduction of a Bill in the new Parliament.

This report was inadvertently not submitted to Professor Newton, who is therefore not responsible for its conclusions.

Report of the Committee, consisting of Mr. E. G. Ravenstein, Mr. Baldwin Latham, *and* Mr. G. J. Symons (*Secretary*), *appointed to inquire into the Climatological and Hydrographical conditions of Tropical Africa.* (*Drawn up by* Mr. E. G. Ravenstein.)

1. The work of your committee naturally falls into two branches, viz., *first*, the collecting and epitomising of all available series of meteorological observations; and, *secondly*, the exercise of a friendly influence over existing, and the equipment of new stations, likely to promote a better knowledge of the climatological conditions of tropical Africa.

2. As regards the first of these objects, your committee have prepared abstracts of the records of sixty-seven stations (including forty-two at which the observations extended over one year). As the places for which there exist records for at least one year number close upon eighty, your committee deemed it advisable to postpone the publication of these abstracts until it shall be possible to present them in a collected form.

Unpublished series of observations have been received by your committee from Captain Chippendale (Upper Nile, 1874–5), Rev. C. Paul (Kipo Hill, 1881), Rev. Mr. Wakefield (Ribe, 1886–7), Rev. G. Smith (Asuan and Wadi Halfa, 1884–5), Rev. R. S. Hynde (Domasi, 1888–9), and Captain Gallwey (Benin, 1891).

Your committee are likewise indebted for useful information and printed meteorological records to Captain Capello, Prof. Neumayer, Dr. Tacchini, Prof. Angot, Dr. Etienne, and M. A. Lancaster.

3. As the funds placed at the disposal of your committee are not sufficient for the establishment of independent stations, with paid observers, they are constrained to confine themselves to the distribution of 'Instructions' specially adapted for tropical Africa, and calculated to ensure the trustworthiness and uniformity of the records, and of blank forms intended to ensure uniformity in the record of observations, and, in a few cases, to the supply of instruments to approved volunteer observers.

The 'Instructions' direct observations to be taken either thrice daily (at 9 A.M., 2 P.M., and 7 P.M.), or once daily (at 9 A.M.), as also at two-hourly intervals on certain term-days.

The 'Instructions' which are being distributed among all observers stationed in Africa are to be supplemented, where necessary, by a copy of the 'Hints for Observers,' issued by the Royal Meteorological Society.

4. The instruments supplied include, as a rule, four thermometers (max., min., wet and dry bulb), and a five-inch rain gauge. The thermometers are placed within a galvanised iron cage, which they have specially devised for use in Africa. Additional instruments are to be supplied as may be required and funds permit, as also a standard barometer, where a guarantee can be given for its safe conveyance.

5. Up to the present, sets of instruments have been granted only to Mr. J. W. Moir (Nyasa) and Captain Gallwey (Benin), but further applications are under consideration.

6. Your committee have expended 50*l.* out of the 75*l.* granted, and they beg to propose that they be reappointed, with the addition of Dr. H. R. Mill, and that a grant be made of 50*l.*, being 25*l.* of last year's grant not drawn, and a fresh grant of 25*l.*

Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Mr. S. BOURNE, Dr. CROSSKEY, Mr. G. GLADSTONE, Mr. J. HEYWOOD, Sir JOHN LUBBOCK, Sir PHILIP MAGNUS, Professor N. STORY MASKELYNE, Sir H. E. ROSCOE, Sir R. TEMPLE, *and* Professor S. P. THOMPSON, *appointed for the purpose of continuing the inquiries relating to the teaching of Science in Elementary Schools.*

THE return of the Education Department issued this year enables your committee to form an idea of the effect which the considerable changes in the Code of 1890 have had on the teaching of science. It will be remembered that the principal differences between this Code and that which had been in force for eight years consist in the optional character of 'English' as a class subject, thus giving more opportunity to the study of Geography and Elementary Science; the alternative courses of these two last subjects; the separation of Euclid and Mensuration as specific subjects; and the abolition of the more theoretical course of Mechanics.

The number of departments of schools in which these class subjects have been examined by H.M. Inspector during these eight years have been as follows:—

Class Subjects.—Departments	1882–3	1883–4	1884–5	1885–6	1886–7	1887–8	1888–9	1889–90
English	18,363	19,080	19,431	19,608	19,917	20,041	20,153	20,304
Geography	12,823	12,775	12,336	12,055	12,035	12,058	12,171	12,367
Elementary Science . .	48	51	45	43	39	36	36	32

The numbers during the year 1890–91 are, for—

English	19,825
Geography	12,806
Elementary Science	173

Thus the non-obligation to take 'English' has at once resulted in a diminution of about 500 departments, and in a similar increase in Geography; while the study of Elementary Science, which had never exceeded fifty-one, and had gradually sunk to as low as thirty-two departments, has suddenly risen to 173. We have no means of ascertaining how many of these have taken one of the alternative courses of Schedule II.

The number of scholars examined in the scientific specific subjects during the same eight years is as follows :—

Specific Subjects.—Children	1882–3	1883–4	1884–5	1885–6	1886–7	1887–8	1888–9	1889–90
Algebra	26,547	24,787	25,347	25,393	25,103	26,448	27,465	30,035
Euclid and Mensuration .	1,942	2,010	1,269	1,247	995	1,006	928	977
Mechanics A . . .	2,042	3,174	3,527	4,844	6,315	6,961	9,524	11,453
„ B . . .	—	206	239	128	33	331	127	209
Animal Physiology . .	22,759	22,857	20,869	18,523	17,338	16,940	15,893	15,842
Botany	3,280	2,604	2,415	1,992	1,589	1,598	1,944	1,830
Principles of Agriculture .	1,357	1,859	1,481	1,351	1,137	1,151	1,199	1,228
Chemistry . . .	1,183	1,047	1,095	1,158	1,488	1,808	1,531	2,007
Sound, Light, and Heat .	630	1,253	1,231	1,334	1,158	978	1,076	1,183
Magnetism and Electricity .	3,643	3,244	2,864	2,951	2,250	1,977	1,669	2,293
Domestic Economy . .	19,582	21,458	19,437	19,556	20,716	20,787	22,064	23,094
Total	82,965	84,499	79,774	78,477	78,122	79,985	83,420	90,151
Number of scholars in Standards V., VI., and VII.	286,355	325,205	352,860	393,289	432,097	472,770	490,590	495,164

The numbers during the year 1890–91 are, for—

Algebra	31,349
Euclid	870
Mensuration	1,489
Mechanics	15,559
Animal Physiology	15,050
Botany	2,115
Principles of Agriculture	1,231
Chemistry	1,847
Sound, Light, and Heat	1,085
Magnetism and Electricity	2,554
Domestic Economy	27,475
	100,624

It will be remarked that the growth in the study of Algebra has continued; that of Mensuration greatly exceeds that of Euclid and Mensuration together in recent years; while the increase is very striking in the case of Mechanics and Domestic Economy. The study of Animal Physiology has lost ground somewhat, and that of Botany has gained. In Physical Science the recent increase in Chemistry has not been maintained, nor that of Sound, Light, and Heat; while Magnetism and Electricity are fast regaining their early popularity. It will be seen that the gross number of passes has largely increased. The returns do not now give the actual number of children examined in Standards V., VI., and VII., but it is possible to arrive at a very close approximation, viz., 497,300. Adopting this figure, we are able to add this year's percentage of the number of passes in these specific subjects, as compared with the number of children qualified to take them, to the returns given in former reports.

In 1882–3	29·0 per cent.
„ 1883–4	26·0 „
„ 1884–5	22·6 „
„ 1885–6	19·9 „
„ 1886–7	18·1 „
„ 1887–8	16·9 „
„ 1888–9	17·0 „
„ 1889–90	18·4 „
„ 1890–91	20·2 „

This shows that the proportion, which decreased rapidly from 1882 to 1888, is now somewhat rapidly improving.

The changes in the Code this year have not been numerous; but two or three of them affect the teaching of Science. There is a small change in Alternative Course I. of Schedule II. (lessons on common things); the subjects for the Seventh Standard now read, 'Familiar Illustrations of Applied Science; *e.g.*, the dwelling; fabrics and clothing; food; warming; lighting, &c.,' instead of 'Other Simple Physical Laws, such as those of light, heat, &c.'

Horticulture has been added to the list of specific subjects; and in Schedule IV. there are definite courses of instruction laid down, both for this subject and Navigation. The first stage of Horticulture is decidedly of a scientific character, as will be seen in the Appendix. The second and third stages are almost purely practical. All three stages of Navigation are also given in the Appendix, as they are all of a scientific character.

There is an alteration in the mode of calculating the grant for specific subjects. Hitherto 4*s.* has been paid for each pass; in future the payment will be '2*s.*, or 3*s.* for each scholar presented in any specific subject. The Department shall decide which, if either, of these sums shall be paid after considering the report and recommendation of the Inspector.' As this will probably involve a slight reduction in the total amount of the grant, there may be less incentive to take a scientific specific subject, but that may not be without compensating advantages. The distinction between the 2*s.* and 3*s.* grant will direct attention to the necessity of good teaching; and many managers may be disposed to drop the more specialised scientific teaching to the higher Standards under Schedule IV.

in favour of a wider course of instruction in Elementary Science throughout all the Standards.

Your committee have always included Domestic Economy in the table of scientific subjects, and its adoption in the girls' schools has become very general. They are aware that it is often taught in such a way as to have little, if any, scientific value; but they believe it is capable of being made extremely valuable in this respect: it should be always taught, as far as possible, experimentally and practically. The simple scientific principles which underlie ordinary domestic operations, such as laying a fire, washing clothes, ventilation of rooms, preparation of food, &c., should be explained. Then the lessons would be rendered far more intelligent and interesting. Arrangements are made by some of the principal School Boards for teaching Domestic Economy in this way.

It goes without saying that the value of the cookery lessons which are now being so much encouraged will depend largely on the knowledge of the principles of Chemistry and Physics possessed by the teacher, and infused into her teaching.

Evening schools have made great progress during the year. The following table will show the comparison between it and the previous year when a scholar could not be examined in more than two special subjects:—

Evening Schools.

(Scholars taking additional or special subjects.)

Years	1 Subject		2 Subjects		3 Subjects		4 Subjects	
	Exam'd	Passes	Exam'd	Passes	Exam'd	Passes	Exam'd	Passes
1889–90	8,973	7,101	6,053	5,454	—	—	—	—
1890–91	13,281	12,071	12,717	11,846	1,317	1,488	232	364

It will be seen that the number of passes is almost exactly doubled, being 12,555 in the former year, and 25,769 in the latter. The Government returns do not enable us to say how many of these passes are made in scientific subjects.

The Education Department has just issued a separate Code of regulations for evening schools. They give a scheme for every one of the subjects of instruction mentioned in the Code, divided over seven years; but managers are not restricted to any of the schemes given. The course of instruction is based upon that of the day schools, that of the class subjects being spread out from five to seven years, and that of the specific subjects from three to seven years. This would imply that scholars are expected to remain seven years in the evening schools; and it also necessitates that their attention should be kept on a limited subject for a whole season. For instance, in Chemistry, the properties of oxygen and hydrogen occupy the whole of the first year, while only those who continue till the sixth year will acquire any knowledge of the numerical laws of Chemistry. Apparently to obviate this very evident disadvantage it is provided that 'the stages of such of these subjects as admit of being so treated may be taken in any order; two or more stages may be taken in one year in less full detail than if one only were taken.'

Of course these day and evening schools lead up to the technical schools of various kinds which are now being rapidly established throughout the kingdom. These do not strictly fall within the scope of the reference to your committee; but it is pleasant to record that the County Councils of London and Middlesex have now followed the lead of the other councils in appropriating the Customs and Excise grant, either wholly or in part, to the purposes of technical instruction.

APPENDIX.

—	15. Horticulture	16. Navigation
1st Stage.	PLANT LIFE. Seeds, nature of, and germination. Requirements, water, heat, air. Soils, nature and composition. What they do and how, what helps, what hinders them. Roots, nature and functions. Branches, fibrils, and root hairs. Stems and branches. Their nature, work, and uses. Helps and hindrances. Leaves, what they are, what they do. Helps and hindrances. Buds and tubers. Leaf buds, flower buds, tubers. Growth. Increase in size, and changes of composition. Formation and storage of food materials. Flowers. Their component parts. What they do. Fruit; changes and development during ripening. Forms and varieties, as apple, strawberry, plum, &c.	Definitions and explanations of the terms used in mathematical geography. Construction and use of charts. The compass. Conversion of magnetic into true bearings, and the reverse. Plane sailing. Traverse sailing.
2nd Stage.	——	Recapitulation. The log. Day's work. Mercator's sailing.
3rd Stage.	——	Recapitulation. Latitude by meridian observation. Explanation of method of determining the error of the compass by an amplitude of the longitude by the chronometer. Deviation of the compass. Description and use of the sextant.

Second Report on the Development of Graphic Methods in Mechanical Science. *By* Professor H. S. Hele Shaw, *M.Inst.C.E.*

[Ordered by the General Committee to be printed *in extenso*.]

Three years ago a preliminary report was presented on the above subject by the Committee, consisting of Mr. W. H. Preece (Chairman), Mr. (now Sir) Benjamin Baker, Messrs. W. Anderson and G. Kapp, Professors J. Perry and R. H. Smith, with the present writer as Secretary, who, at the meeting in the following year, was requested by the Sectional Committee to draw up and complete the report. Owing to causes which were explained in a letter to the Committee last year, he was unable to do this in time for the following meeting, and now begs to present the result of his work up to the present time on the subject.

The preliminary report gave a list of a number of works which avowedly dealt with graphic methods, but at the same time it was stated that a large number of standard works based to a great extent on such methods, or in which such methods were frequently applied, were excluded from the list.

It does not require much acquaintance with the subject to realise that there is scarcely a treatise or publication dealing with mechanical science that does not employ some kind of graphical expression as a means of exposition or calculation. How great the range is may be gathered from a consideration that graphic methods really include every way of representing numerical quantities by means of drawing, except 1. The representation of actual bodies; and 2. Purely geometrical construction. Hence we have to go back very early in the history of mechanical science to find the first graphic treatment of the subject.

A study of the list of references to graphic applications in the scientific literature of this country appended to this report will show that gradually, but with an ever-increasing rate, it has become the custom to employ representations of numerical results graphically, and to suggest and use the solutions of various problems by graphic methods.

These two purposes, viz.—

1. Representation of results by means of plotted curves and autographic diagrams;
2. Solution of problems by graphical methods,

seem to suggest a satisfactory way of dealing with the subject. At the same time, no hard-and-fast distinction must be insisted on, because a curve, although chiefly useful for the purpose of representing the general results of an experiment or calculation, may be employed, by means of interpolation or otherwise, to effect a calculation.

(1) It would be quite legitimate in this report to trace the development of the represention of results, but the best method of procedure is to state the results which have been achieved, as this aspect is the practical and useful one.

Inasmuch as every possible kind of numerical quantity can be plotted, it would not be possible, even if it were desirable, to give anything like a complete list of the subjects which have been, or may be, plotted. Further, in dealing with instruments used for the purpose, there must be

omissions, because descriptions of many such instruments have not been published; hence the object of the writer in dealing with this part of the report has been to give a concise statement of the progress and present state of the subject.

At the same time the difficulty of ascertaining what subjects in mechanical engineering have been treated graphically in current literature is very great, and nothing less than an examination of every page of engineering journals and scientific papers suffices for this purpose, since no intimation of graphical treatment is usually given in the index. Hence a list of references has been added to this report, arranged under suitable headings of the more important applications of mechanical science, wherever such applications have been graphically treated. In one column the names of the subjects are given under which the article is found in the journal; in another, the description of the graphic diagram; in another, the author's name. The arrangement of matter under each heading is in the order of the year of publication, so that anyone searching for graphical records on a certain subject will see at once what is old and what is new.

(2) Very different, however, is the case of the graphical treatment of problems. This is a subject of very divided opinion, whereas the mere representation of results has settled down into recognised lines and methods of operation. Great as the progress has been in this direction, it will be seen that there is a wide field for discussion in the present state of the question; hence in this portion of the report an attempt has been made to present the views of different schools of thought, and to state the results achieved up to the present. At the same time, the question is far too wide to be treated in the present report in a way at all justified by its importance, and it is a question for the Association to decide whether a further report, dealing more fully with foreign literature and practice in graphic methods in relation to mechanical science, is not desirable.

To the treatment of the subject thus divided there is prefixed a statement of the geometrical principles involved in the methods of graphical representation. This preliminary statement is necessary to show both the possibilities and methods of graphical records, as well as to premise the considerations in the second portion, dealing with calculation.

The foregoing remarks will explain the following scheme of the report:—

Scheme of Report.

I. Geometrical considerations involved in (1) the representation of results graphically, and in (2) graphical calculations:—

1. Use of one dimension of space corresponding to measurement from one fixed point in a plane, enabling one variable to be dealt with. The use of two dimensions of space corresponding to the measurement from two fixed points in a plane, enabling two variable quantities to be represented by the position of a point. The use of three dimensions, or of representation of three variables by the positions of a point, involves the use of models or stereotomy, and is excluded from consideration in treating of graphical methods.
2. Practical distinction between analytical treatment and geometry of position. The Graphical Calculus.

II. The representation of results:—

1. The plotting of diagrams; the use of squared paper. Growth of the method. Plotted tables. Contributions on Naval Architecture, by Mr. H. H. West; and on Electrical Work, by Mr. F. G. Baily. Applications in civil and mechanical engineering.
2. Instruments for drawing known curves used with graphical methods. Improvements in simple drawing-instruments. Elliptographs. Drawing the parabola. Harmonic curves: the involute; cycloid; spirals, &c. The Gabarit. The Integraph.
3. Self-recording instruments. Marking arrangements. Modes of actuating surface for receiving the record. The movement of the recording arrangement. Instruments for recording (*a*) levels; (*b*) pressure; (*c*) magnetic attraction; (*d*) velocity; (*e*) temperature; (*f*) vibrations and shocks; (*g*) results of mathematical operations; (*h*) chronographic results.

III. Graphical solution of problems:—

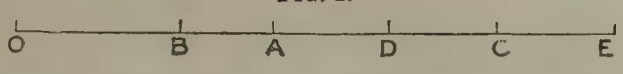
1. Consideration of modern methods of graphical calculation, chiefly in view of Continental usage and opinions concerning the application of projective geometry in graphic statics.
2. Addition of parallel segments. Sliding calculation and slide rules. Shearing force and load diagrams.
3. Addition of non-parallel segments. Summary of the applications of the principle of reciprocal figures.
4. The applications of graphical multiplication. The rectification and calculation of areas. Summary of the problems in engineering to which methods of graphical multiplication are applied.

I. Geometrical Considerations.

Let us suppose we have a plane surface, or what may be developed into a plane surface, *e.g.*, a paper wrapped upon a cylindrical barrel, which we propose to use for graphical purposes.

If we take any point upon the surface, we can represent any numerical quantity by its distance from some other fixed points, the position of which we suppose to be known, writing beside the point, or representing by means of some notation, what particular thing the numerical quantity is supposed to refer to. By taking a number of points we may represent any number of numerical quantities by their distances from the fixed point, and there is no limit to the number of ways in which we may do this; for instance, we may take them ranged along one straight line, just as in the graduation of scales and similar instruments, where each reading measures the distance from the zero of the scale; as, for instance, the kind of graphic record of magnitudes represented by the distances OA, OB, OC, OD, and OE in fig. 1.

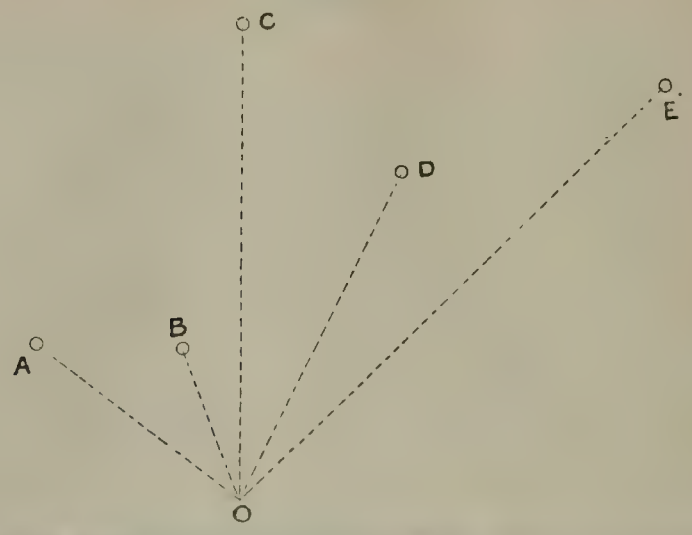
Fig. 1.



Instead of a point being taken along a straight line, *i.e.*, in one direction, the same points may be taken in different directions, as shown in

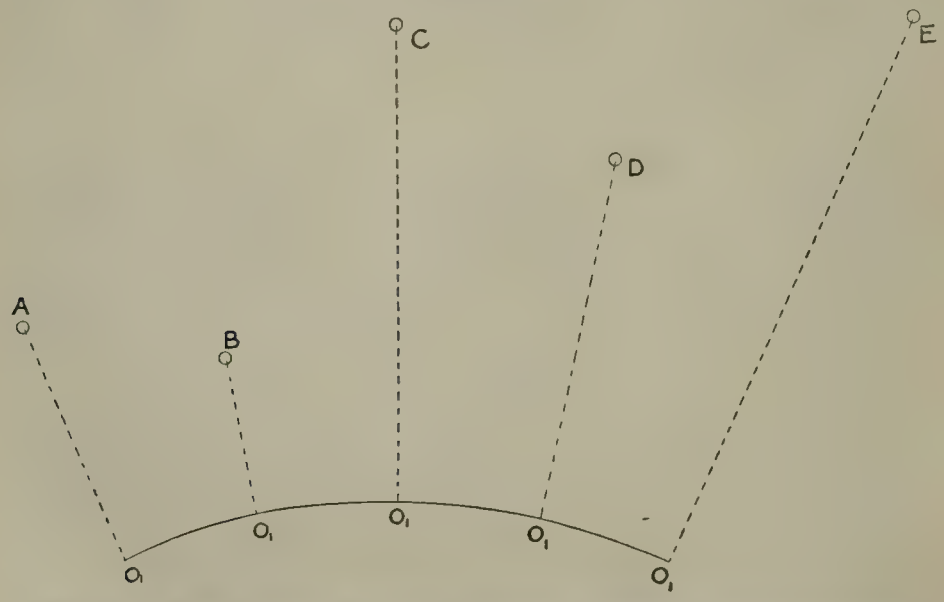
fig. 2, and the relative distances of each made more obvious upon inspection by the line of direction being separate and distinct. A still clearer result is obtained by adding a constant length to each distance, which is

FIG. 2.



equivalent to taking the fixed point farther away, and measuring the distances along radii from an arc drawn with a fixed distance as centre, as in fig. 3.

FIG. 3.



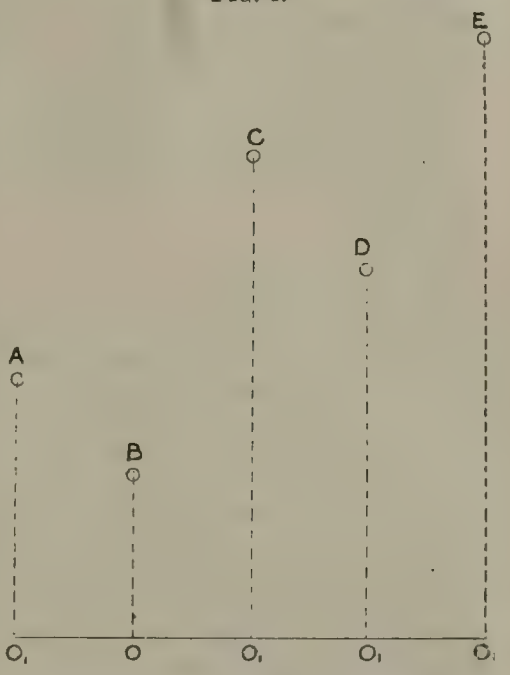
When a fixed point is taken infinitely distant, the arc becomes a straight line, and the distance measured perpendicular to it and parallel to each other, as in fig. 4.

This is the most common and convenient way of popularising statistics graphically, and enables various numerical quantities to be compared.

For instance, in a paper read by Mr. Price Williams we have the various data about different railways compared in this way.[1]

This method of employing only one dimension of space, or using the scalars of Sir W. R. Hamilton, can only represent a limited number of isolated facts, and, except in the application of scales and for the purposes of slide-rule calculation, has little interest.

FIG. 4.



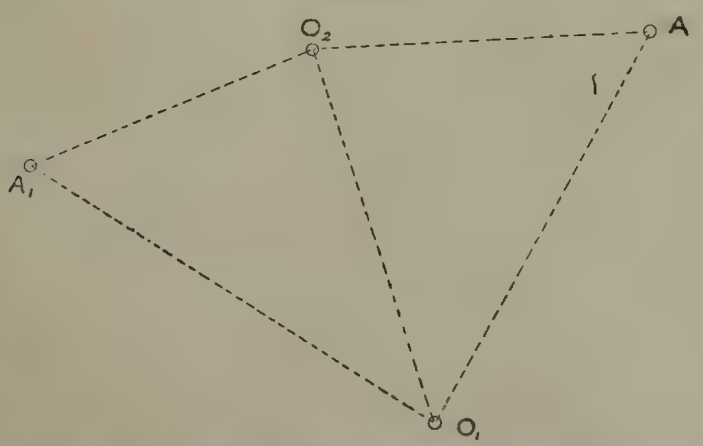
Suppose now a second point be taken O_2; then the distance of A from it may also represent another numerical quantity, and is quite independent of its distance from O_1.

Conversely, having two quantities to represent a point, A may be found, which is at distances from O_1 and O_2 representing respectively these quantities (fig. 5).

It is clear that by drawing arcs of circles there are two points (A and A_1, fig. 5), and only two, which can be found to correspond with these results—viz., the intersection of the arcs. These two points are situated symmetrically on either side of the line through O_1 O_2.

So with distances corresponding to OB, OC, . . ., fig. 4, two points being found in each case; but since the fields separated by O_1 O_2 are exactly similar to each other and symmetrical in relation to the position of the points A, B, C, D, . . ., only one set of the two situated symmetrically on oppo-

FIG. 5.



site sides of the line joining O_1 O_2 need be considered. Thus, considering one set of the two symmetrical systems of points, it may be said that each

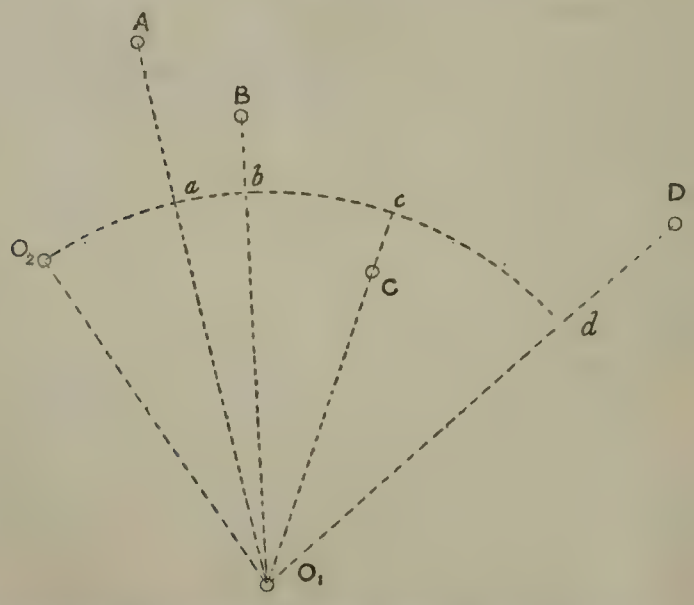
[1] *Proceedings of the Institution of Mechanical Engineers*, 1879, p. 96.

point on the surface represents by its distance from two fixed points two numerical facts. By the use of a third fixed point the power of representing results is in no way augmented, for the position of A is fixed by its distance from O_1 and O_2, so that no fresh fact, independent of the two previous ones, can be represented by its distance from O_3. This is not a mere accident, to be avoided by any geometrical device, but is the result of using for a graphic diagram two dimensions of space in the form of a surface, either plane or developable into a plane. Hereafter a device will be noticed by which, representing artificially three dimensions of space, a third independent variable may apparently, though not really, be represented. Hence it may be said that two conditions determine the position of every point, and, conversely, every point represents two conditions, and two only.

Just as with one fixed point, when one dimension of space only was employed, any number of numerical facts could be represented by taking any required number of points, so with the use of two fixed points, or of two dimensions in space, any number of facts could also be represented. Now it does not matter in what way the two measurements are used, so long as the position of the point on the surface is fixed by them; and as for practical purposes the use of the two points in the above manner is not convenient (one condition, for instance, being that the sum of the lengths must be equal to or greater than the distance between the fixed points), other ways of attaining the same results are employed.

(1) Using one point, say O_1, as a centre, an arc is drawn through O_2; a given distance measured round this arc from the latter to a point, A, is taken for one of the numerical quantities, and through the point a so formed a radius is drawn from the other fixed point, O_1, and along this radius the second quantity is measured, represented by O_1 A, fig. 6.

FIG. 6.

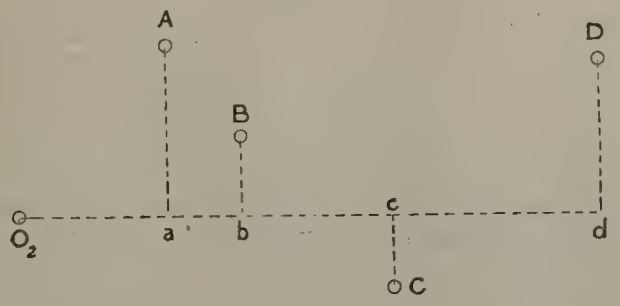


In this way any number of quantities—O_1 A, O_1 B, O_1 C—are represented. This method is what is known as the use of polar co-ordinates, the distance from O_1 being the polar distance, and the distance from O_2

the measure of the angle which the radius vector, or direction of the polar distance, makes with the line O_1 O_2. The direction in which the distance is measured from any one point to any other point can always be found and stated numerically with reference to the two fixed points by drawing a parallel to the direction in question through one of the fixed points. The direction can then always be stated in terms of distance from the other of the two fixed points at which the arc cuts the radius vector.

(2) Just as when dealing with only one fixed point, so when dealing with two we may remove O_1 to an infinite distance, and obtain, as before, a straight line for the arc, and from this the distances to A, B, C, D, E, can be measured (fig. 7).

FIG. 7.



The distances from O_2 are now measured along a straight line, which is the base line of the single-point method, the line through O_1 O_2, which may be called the vertical line, being perpendicular to it. If we next suppose O_2 to be also removed to an infinite distance, magnitudes previously measured along the base line may now be measured from any fixed vertical line, and parallel to the base line, since all parallel lines pass through the same point when it is at an infinite distance.

This is the Cartesian system of co-ordinates, the distance of any point from the base and vertical lines being respectively the ordinate and abscissa of the point. The direction in which any distance is measured between any two points on the surface can be stated just as easily as with polar co-ordinates by the ratio of the distance between the points measured parallel to the vertical axis and the distance measured parallel to the horizontal axis. This is, of course, the same thing as taking the ratio of distances between the points, measured respectively in the directions of the two fixed points, which are now, however, imaginary.

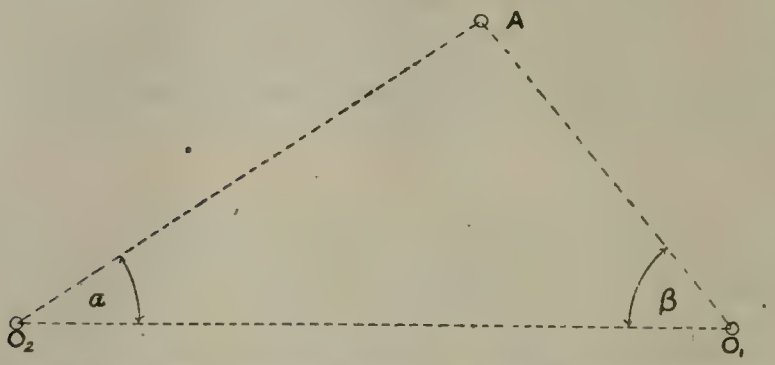
Except for the matter of convenience, the use of two points, or the use of polar co-ordinates or of Cartesian co-ordinates, might with equal advantage be employed, and it is quite possible that just as Descartes invented and developed the last-mentioned system, so some other method might be found still more serviceable for graphical purposes. Thus, for instance, it does not matter if what corresponds to the base line and vertical line are not at right angles to each other, or the distances are taken in directions parallel instead of perpendicular to them, which is in fact the method of oblique co-ordinates. Or we need not use the idea of direct measure of lengths at all; we may employ with the two fixed points two angles as in fig. 8 and find A as readily; for we know that the solution of a triangle can be found from two angles and the included side as easily as with three given sides.

The general conclusion arrived at is that, no matter what system may

be used, two facts, and two facts alone, can be represented by the position of each point on the surface.

The practical applications of the two numerical facts represented by each point must now be considered. In the case of the single fixed-point

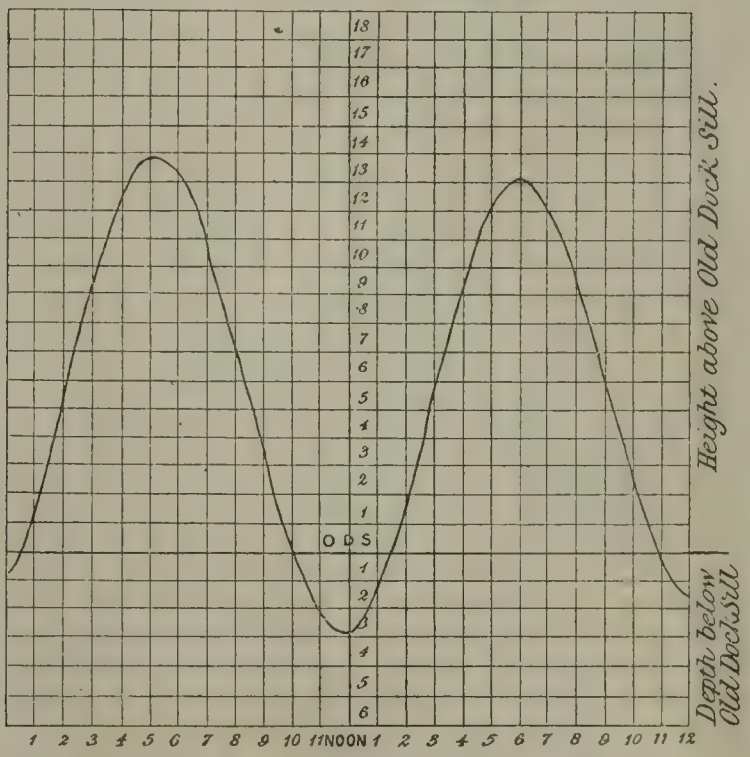
FIG. 8.



system, some means of notifying each quantity equivalent to writing upon it the thing represented was required.

Suppose that in fig. 4 the height of the tide at different times had been represented by the distance O_1 A, O_1 B, &c. Now, instead of

FIG. 9.—Tide Curve, Liverpool, May 2.



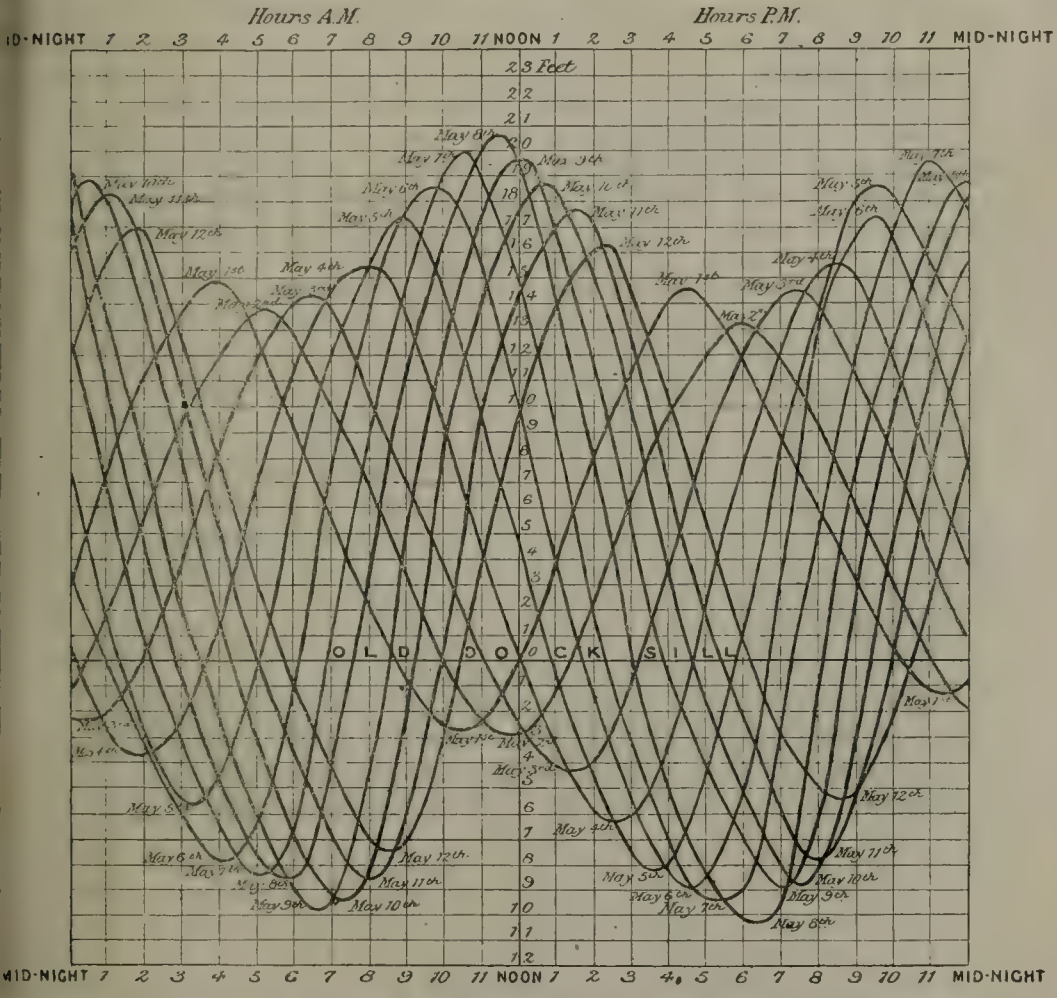
writing the hour of the tide on each distance from the base line, or even denoting these different hours by A, B, C, D, a much better plan is to take the time as a second quantity, to be measured from the second point,

or, if Cartesian co-ordinates are used, the heights of the tide as ordinates, and corresponding times measured from a certain hour, say noon, as abscissæ. Such an actual diagram is given (fig. 9).

This at once represents two facts, which have an intimate connection, and we can see the great advantage of the two-dimension system, for now we compare graphically the effect of change of time on the height of the tide—that is to say, not merely the relation of the various heights to each other, but their relative value as affected by lapse of time.

This is, however, but one of the two advantages: the other is that,

FIG. 10.


Hours A.M.
Hours P.M.
MID-NIGHT 1 2 3 4 5 6 7 8 9 10 11 NOON 1 2 3 4 5 6 7 8 9 10 11 MID-NIGHT
Feet
OLD DOCK SILL
MID-NIGHT 1 2 3 4 5 6 7 8 9 10 11 NOON 1 2 3 4 5 6 7 8 9 10 11 MID-NIGHT

having no longer to notify each value of the height by some symbol to show what hour of the tide it corresponds to, thus necessarily limiting the number of heights which could conveniently be given, each point representing height now has its particular time given by its abscissa. Hence an unlimited number of heights can be given, since an unlimited number of points can be shown. As a matter of fact, the tide, rising and falling with the lapse of time, necessarily has an infinite number of heights, and the points representing these merge into the continuous line given in fig. 9.

This continuous line is the result of taking any two quantities which gradually change, and may be plotted by other methods in other ways such as those already mentioned. There is no limit to the number of such lines or rows of points, except the very practical one of convenience. Hence we might, instead of having the tide for one day, as shown in fig. 9, have expressed graphically the tides for various different days in succession, as in fig. 10 (which, together with fig. 9 and other information, has been kindly supplied by Mr. Anthony G. Lyster, assistant-engineer, Mersey Docks and Harbour Board), which represents the successive states of the tide from May 1 to May 12, 1892; but in the latter case it becomes necessary to distinguish each particular curve in some way, for instance as shown in the figure, by writing the corresponding day upon each curve, just as it was necessary to do when a number of distances were employed to represent isolated facts, as in figs. 4 and 5.

The practical limit is placed by the number of curves which can be recorded on a single diagram without producing confusion; for instance, suppose that instead of plotting the tidal results for twelve days, as in the diagram given, for any date, it had been desired to give them for every possible date—as, for instance, might be calculated by Lord Kelvin's tide-predicter—it is quite clear that, even for one year, it would have been quite impossible to do so without destroying the clearness of the diagram; and taking the time over a sufficient period would have merged the curves into one another, and covered the surface of the paper.

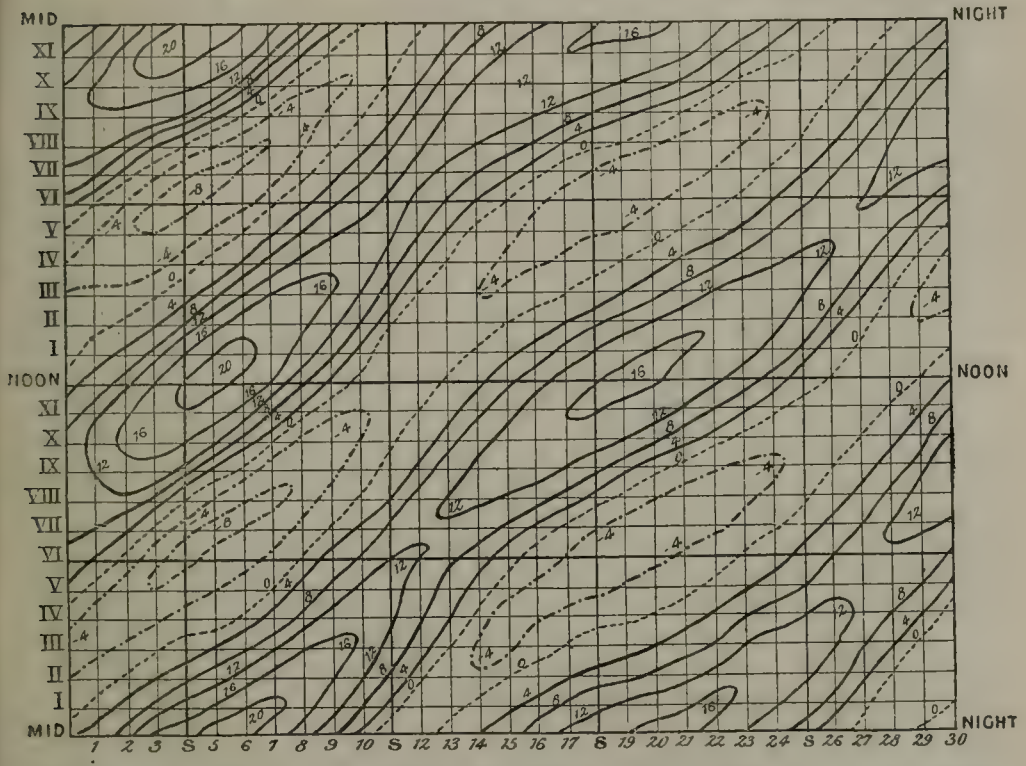
The truth is, there are now three variable quantities, the changes in which it is desired to represent by the changing position of the point in space, and this can no longer be done in a plane surface. The limit of what can be represented by a true graphic method has been reached, and models or some equivalent process of representation, such as shading, equivalent to the delineation of the surface of a solid occupying three dimensions of space, must be employed. A further illustration will make this point clearer.

Let fig. 11 represent another way of plotting similar tidal data, the days of the month being now represented as the abscissæ; then for a given spot (in the case taken, the dock-sill at Liverpool) and for a given time (November 1888) we can trace for every day the time at which the tide has reached any particular height at the dock-sill. Take, for instance, the case of the tide when it is at datum level, which is shown in the figure by dotted lines, and marked zero. This for the first day of the month in question occurred at 1.30 A.M., on the 5th at 3.40 A.M., on the 12th at 1.55 P.M., and so on; but, moreover, as it occurred four times in the twenty-four hours, these facts are recorded along the four different lines, which are distinguished in the way mentioned.

Now, if it be desired to trace the lines for each day at which any other levels occur, it is only necessary to draw fresh lines. For instance, let the case be taken at which the height is 4 feet below the sill; this is shown by a series of curves in dashed and dotted lines, thus — · — ·— ·, and marked −4. The times at which the tide is at the level of −4 on the day abovementioned are: on the 1st, 2.45 A.M.; on the 5th, at 5 A.M.; but on the 12th the curves do not intersect the ordinate at all, showing that on the twelfth day of the month—that is, during neap tides—the level of the tide never falls 4 feet below the sill. A number of heights can be taken, as shown in the diagram, which gives them for differences of level of 4 feet, and it is clear that if any smaller differences of height are required

the lines will be closer together, and the diagram will tend to lose its clearness. These results can, however, be transferred to a model, each difference of level being represented to scale, and the different heights being shown as a series of steps. In this case, however, not the slightest confusion arises in producing every possible variation of height, which was done in one section of a model exhibited before the Section by forming a continuous slope by means of plaster. Measurements can be taken at any point of any of the three variable quantities, namely, the day of the month, or hour of the day, or height of the tide, when any two out of the three are given. The model in question shows that the diagram

FIG. 11.—Tide Diagram, Liverpool, November 1888.



The curves give differences of 4 feet from Old Dock-sill. Lines marked - - - - - give datum level. Lines marked — · — · — · give levels below datum level. Thick lines give levels above datum level.

NOTE.—The Old Dock-sill is 4·65 feet below ordnance datum.

may be practically regarded as an example of the use of contour lines; and just as contour lines are generally employed for giving various heights of mountains, and indicate the slope or steepness of various parts by their proximity to each other, so the rapidity with which the tide rises and falls on certain days of the month is equally well shown by the closeness of the lines of the tide diagram.

For instance, the tide rises and falls much more rapidly on the 4th than on the 11th, for in the former case the intersections of the curves by the ordinate are much more close together than in the latter.

This use of contour lines is generally employed on maps, not only for representing the heights of mountains, but for showing the density of

population, barometrical readings, temperature, &c. Contour lines are also used with Cartesian co-ordinates—for instance, with isothermal curves of air expansion. They are referred to by French writers in various treatises under the title of 'courbes d'égal élément,' and have the same relation in graphic diagrams with regard to two dimensions of space as the mere setting up of lengths in one dimension of space illustrated in figs. 4 and 5, requiring some distinguishing mark or notation, as in fig. 11, for each particular line or curve employed.

As contour lines are thus shown to be a special case of curves formed by the combination of two variable quantities, they need not be further alluded to, although it is worthy of consideration whether in many cases where models have been employed—such, for instance, as the surfaces used by Professor Thurston in his researches on 'Ternary Alloys'—they might not be conveniently replaced by the use of such contour lines which involve only graphic diagrams.

There are, it is true, ways in which certain relations of three variable quantities may be represented graphically. Thus the method used by Professor Clerk Maxwell for the composition of colours was suggested [1] by Sir G. G. Stokes for representing the results of Dr. Alder Wright's experiments on 'Ternary Alloys.' In this case any triangle being taken (preferably an equilateral triangle), the quantity by weight of each of the three substances used in the alloy may be supposed to be respectively placed at the three apices, and the centre of gravity of all three found. This being always some point in the plane of the triangle, the position of the point on the surface represents the composition of the alloy. A bounding curve, called the 'critical curve,' is then drawn through the points so found, corresponding to the proportion at which the alloys refuse to remain in combination, but separate into two substances, by means of which curve certain important facts are made evident. The diagram, however, does not really represent three variable relations, because it is clear that if every possible composition were tried the surface would be covered with points, those only which lie along the curve in question actually representing the result of the graphical construction.

The fact that the results of three variable quantities cannot be truly represented upon a plane surface has been insisted on, both to clear the way for what follows and because the references to this are often somewhat misleading; thus Favaro, in his 'Lectures on Graphic Statics,' [2] says truly, p. 147: 'Every curved surface to really represent with reliefs requires the three dimensions of space which correspond to the three variables of which they represent the relation,' but goes on immediately after to say: 'But one can by means of a notation as simple as expressive replace constructions in space by traces entirely contained in a plane,' and then proceeds to describe the system of contours, which it has been shown only partially represent the result of the simultaneous variation of three quantities; and, indeed, whatever trace is taken on the plane can always be developed into two, being the intersection of surfaces of an irregular cylinder with the curve surface in question. In his translation of the above work M. Terrier proceeds to give in an appendix a number of cases of what he calls stereograms—a term first proposed by Professor

[1] *Proceedings of the Royal Society*, vol. xlix. No. 298, p. 174.

[2] *Leçons de Statique graphique*, par Antonio Favaro. Traduites de l'italien par Paul Terrier, deuxième partie, 1885. Gauthier-Villars, Paris.

Messedaglia—which represents results capable of representation by ordinary methods of graphical treatment.

Graphical methods of representation are thus seen to narrow down to the use of points and lines upon a plane surface, at the same time with an unlimited range of application.

Regarding the geometrical constructions involved in graphical calculation, it is now clear that the whole subject turns on the intersection of lines, that is to say, on their relative position. Hence, it is not surprising that when any given thing can be represented, not merely in magnitude by the length of a line, but also in direction by its position in space, we have a direct application of that branch of geometry which deals with the position of lines and planes, and their intersection with each other, the relations of which are independent of numerical magnitudes. This kind of geometry, which is called, under the various names of 'modern geometry,' 'higher geometry,' 'projective geometry,' or, best of all, 'geometry of position,' has advanced enormously in importance in recent years, and has become a subject of instruction chiefly on the Continent, in the polytechnical schools, mainly from the fact that the most important of all numerical quantities in mechanics which can be represented graphically—namely, force—being capable of direct and complete representation by lines, enabled the general applications of the properties of geometry of position to be at once made. A large number of propositions, which previously had little practical interest, thus assumed a physical meaning, which makes them of the greatest value, and the science of graphic statics, which occupies probably the largest place in Continental engineering schools, owes no small measure of the importance in which it is held to the fact that it affords a high mental training in geometry, which has at the same time direct practical value.

It is a remarkable fact that the teaching of geometry of position as an object in the curriculum of foreign schools is owing, in a large measure, to the publication of Culmann's treatise on graphic statics. Weyranch, in his 'Ueber die graphische Statik—zur Orientirung,' and quoted by Jay Du Bois in his 'Graphical Statics,' says:—

'After von Staudt, the strict geometry of position remained a long time disregarded, while the synthetic geometry of Steiner has enjoyed, without intermission, till the present day a special preference on the part of mathematicians. Culmann gave the impulse to a change in this respect. In his "Graphical Statics" he rests directly upon the work of von Staudt, and, with something more than boldness, assumes a knowledge of the geometry of position among all practical men. Such a course was not indispensable for the foundation of his method, and impeded the spread of the graphical statics; but by it the geometry of position gained. This last had next, of necessity, to be introduced into the Zurich Polytechnic, and thus arose the first, until now, only complete text-book upon the subject, the "Geometrie der Lage," by Reye (Hanover, 1868), as the direct result of the "Graphical Statics" of Culmann. Since then the modern geometry has been introduced into all technical institutions throughout Germany, and thus placed at the disposal of the arts and sciences.'

This subject is so important that it will be alluded to again in dealing with graphic calculation. At the same time it may here be pointed out that while, as in plane projective geometry, the relative position of lines may be manipulated graphically, their position may perfectly well and completely be represented by measurement from two fixed points, so that

we may use either geometrical construction or mathematical calculation of trigonometry and algebra; that is to say, the analytical process may be employed to follow the same operations and register the same results.

As a result of the increasing introduction of graphical methods, a science known as the Graphical Calculus has arisen, though until a few years ago there was no complete treatise in the English language under this head. Now, thanks to Professor T. Hudson Beare's translation, there is available for English readers the 'Calcolo Grafico' of Professor Cremona.[1] This work deals with the modern use of lines in geometry, as initiated by Moebius, and then in subsequent chapters the combination or addition of a number of segments, which is made use of chiefly for reciprocal figures of framework in graphic statics; graphical multiplication, which is applied in such important problems as bending moment, moment of inertia, deflection, and other matters; the extraction of roots; reduction of plane figures, so as to enable their area to be found graphically; the finding of the centre of parallel forces, under the title of 'centroids'; and finally some useful propositions on the rectification of the circular arc. Many of these propositions the author in a preface to the English translation states are not new, and have been known to English writers, but there is much that has never been previously written in English, or brought together in one book.

It is therefore unnecessary to refer in detail to these applications of geometry treated of in the above work, but it may be remarked that the more careful use of lines and notation on the principles set forth by Moebius would often prevent much confusion and unnecessary explanations—sometimes not even then leaving the subject particularly clear—in various books dealing with graphical applications.

II. Graphical Representation of Results.

1. *The Plotting of Diagrams.*

The plotting of experimental results of all kinds, usually by the use of Cartesian co-ordinates, has become a universal practice. Scarcely a paper containing numerical results is presented to the scientific world in which this system is not employed, while in connection with experimental research in all laboratories in which instruction is given, the operation has become probably nearly as common as the use of arithmetic. This has led to the use of 'squared' paper, which has greatly facilitated the process of plotting, and the annexed figure (fig. 12) gives a number of different examples of squared paper in common use.

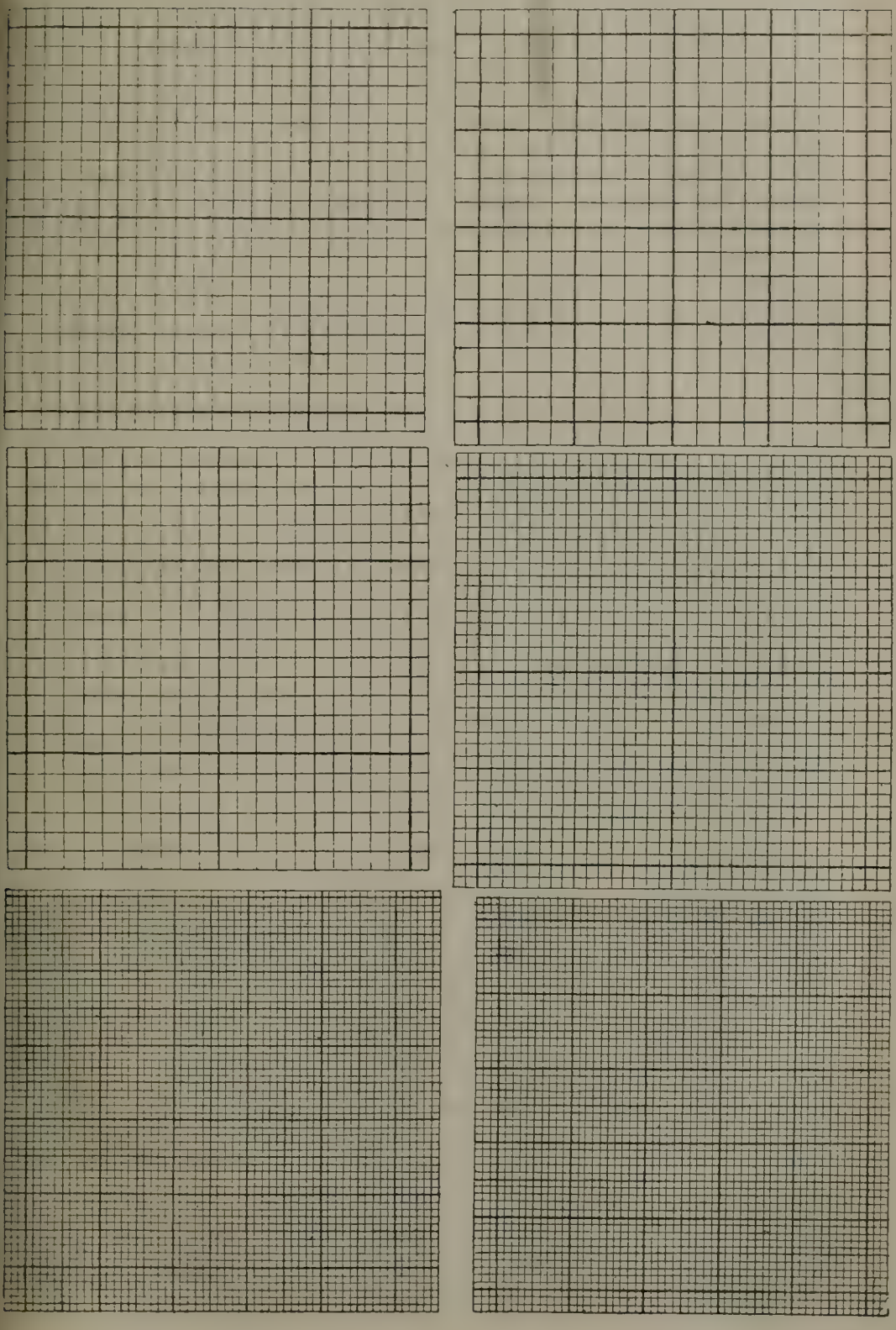
For many purposes where special work is done, ruled paper of a particular kind is used instead of squared paper. For instance, in plotting the results of experiments with the Thurston Testing Machine for torsion the lines are ruled radially, as shown in MacLay's book on 'Loci' (p. 60).

There are three principal purposes for which plotting of results may be employed:—

(1) For experimental work, in which the results of a certain number of experiments are plotted, and the curves drawn through them, so as to

[1] *Graphical Statics*, by Luigi Cremona, translated by Thomas Hudson Beare. Clarendon Press, Oxford, 1890.

FIG. 12.



enable the general laws to be determined. Thus we find Regnault, in his classical experiments on the properties of steam, plots his results, as, for instance, the 'saturation curve,' which was drawn in terms of pressure and volume, on a copper plate. Almost all experimental work, such as that of Ramsay and Young on 'Vapour Tensions,' contributed to the Royal Society, Beauchamp Tower on 'Friction of Bearings,' Kennedy on 'Engine Trials,' Thurston on 'Lubricants,' has been thus plotted; and amongst numerous examples which might be quoted of the plotting of results leading to the discovery of a law, we may quote the results of tests on the strength of cement, which Professor Unwin has shown to obey comparatively simple laws, the curves of test approximating to a parabolic curve.[1]

The following remark, taken from the preface of the important treatise of Ganguillet and Kutter,[2] well illustrates the advantages of this method: 'In studying the subject we made continual use of the graphic method, and were eventually led to the recognition of the elements affecting the flow of water, and thus to the development of our general formula.'

(2) It has become recently more and more the practice to plot the results of laws, and experimental data, which would always have been given a few years ago in the form of a table. Thus we find in Molesworth's 'Pocket-Book' plotted results for safe loads on various spans of girders (p. 125) and for moving loads (p. 162). In Professor Unwin's book on machine design we find a graphic table of the proportions of pipes (p. 16, Part II., 1890), and another on the proportions of keys (p. 171, Part I., 1890), and in a more recent book by Foley[3] we have the following examples of the graphical method:—Plotting of curves for the expansion of steam for purposes of actual reference, the proportions of valves, the extension and loading of springs, of friction, of the proportion of the teeth of wheels, of proportions of belts, strengths of ropes, of the displacements of ships, of the proportions of propellers, bolts, pipes, boilers, furnaces, tubes, girders, coal consumption, surface condensation, &c., all of these being on a large scale and elaborately prepared, so as to enable actual proportions to be obtained by their use.

Falling under the head of 'graphical tables' are the constructions devised by M. L. Lalanne,[4] and published under the following title:—'Mémoire sur la Table Graphique et sur la géometrie anamorphique appliquée à diverses questions qui se rattachent à l'art de l'ingénieur.' An example of one of these tables, called by the inventor an 'abacus' (*abaque*), was shown as a wall diagram to the Mechanical Section. The ordinates and abscissæ of this diagram are not numbered according to their actual values, but are logarithmic, exactly as the scale on a slide rule. By means of this diagram operations of multiplication can at once be performed, and by a slight modification products such as a^2b and the $\sqrt{a^2b}$ can be readily obtained.

Professor Culmann, in his book on graphic statics, gives another table in which parabolic curves are plotted, by means of which a large number of questions of earthwork cuttings and embankments can be

[1] *The Testing of Materials of Construction.* Professor Unwin, B.Sc. Longmans, Green & Co.

[2] *A General Formula for the Uniform Flow of Water*, by Ganguillet and W. R. Kutter. Trans. Hering and Trautwine. Wiley, New York, 1889.

[3] *Mechanical Engineer's Reference-Book.* Foley. Crosby, Lockwood & Co., 1891.

[4] *Annales des Ponts et Chaussées*, 1846, tome i.

readily determined. The 'Pocket-Book' of Trautwine on earthwork contains a large number of cases in which the results of elaborate tables are plotted, and can be used much more readily than the tables themselves.

Many other examples might be cited, such, for instance, as a curve given by M. Marey,[1] in which are plotted various data concerning suspension bridges of a certain type, the weights respectively of iron and other metals, and wood, as well as the cost, being given for every span within a certain limit.

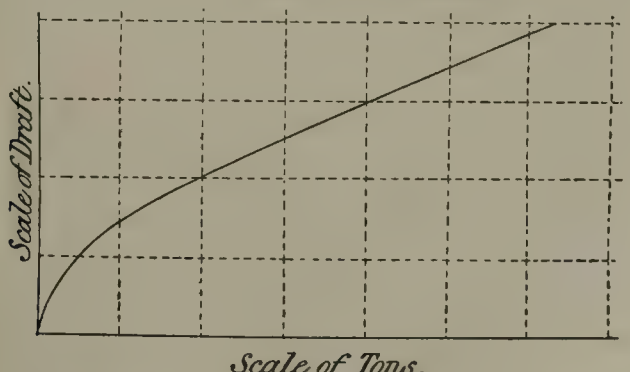
In fact, there is no limit to the possible number of graphical applications, since they can be employed whenever the result is required of two quantities which vary simultaneously. It must be remarked, however, that the result given by their use cannot be regarded as very accurate, though probably they admit of as close a degree of accuracy as it is usually possible for an engineer to attain in practical work, and certainly have the unquestionable merit of preventing any great error which may occur as the result of calculation, which therefore they may well be used to check.

(3) The last, and possibly the most important, object of plotting results is the regular work of the engineer or naval architect, in which he sets down the results of a few calculations in order to be able to determine any others which he may require in the same series. This, as graphically treated, becomes a very simple process, and amounts to merely drawing a curve through the points which he has found and plotted, and interpolating all the values that he requires. This, if performed mathematically, would require difficult and often impossible calculations, and it is just for such purposes as this that the graphical method is indispensable to, and will be invariably adopted by, practical men.

Mr. Henry H. West, of Liverpool, M.Inst.C.E., Member of the Council of the Institution of Naval Architects, has kindly supplied the writer with the following remarks, which admirably illustrate this point in connection with naval architecture:—

'The principal use which naval architects make of graphic methods is to record in the form of curves the results of calculations made for certain given conditions, and from these to arrive at similar results for other

FIG. 13.—Curve of Displacement.



conditions by interpolation of new points in the curves corresponding with the required new conditions. Beyond this, graphic methods are little, if at all, used as a means of calculation.

[1] *La Méthode graphique*, par E. J. Marey. G. Masson, Paris.

'Probably the most ordinary application of graphic representation in this connection is the "curve of displacement," in which the ordinates are drafts in feet, and the abscissæ are tons. For merchant vessels this curve is usually of the character shown in the accompanying sketch, fig. 13, the upper part of the curve approximating very closely to a straight line.

'Another curve much used is a curve of "tons per inch of immersion," in which the vertical scale is again a scale of drafts, and the horizontal scale a scale of tons per inch.

'Its character is generally somewhat like fig. 14. It is used in calculations of trim, and to estimate small variations of draft in terms of tons, or *vice versâ*.

'Another curve of considerable service is a "curve of midship section areas," in which, again, the vertical scale is a scale of drafts, and the

FIG. 14.—Tons per Inch of Immersion.

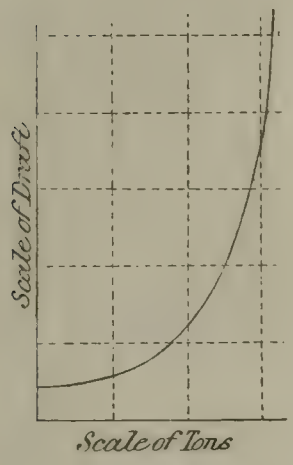


FIG. 15.—Curve of Block Coefficient.

horizontal scale, a scale of superficial feet. Its general character is very similar to that of the curve of displacement. The use of the curve is to estimate the area of the furrow, so to speak, ploughed in the water by the ship's forward progress.

'Another curve which is sometimes plotted is the curve of "block coefficients," or the ratio which the volume of the immersed part of a vessel bears to the volume of a parallelopipedon of the same extreme dimensions, and is useful for comparison of ship with ship.

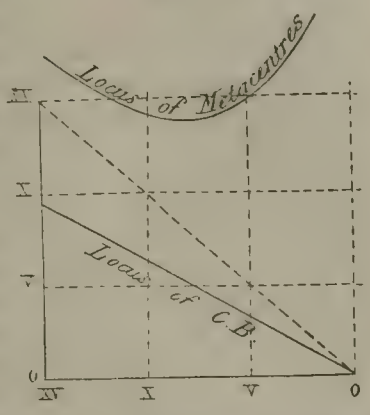
'Its vertical scale is a scale of drafts, and its horizontal scale, a scale of decimal parts, or percentages. Its general character is much like that of the curve of tons per inch of immersion (*see* fig. 15).

'Somewhat different kinds of curves are the curves of "locus of metacentres" and of "locus of centres of buoyancy" (fig. 16). As these points are heights on the same vertical, varying with the draft of the vessel, which may also itself be considered as a height, all the points representing different conditions would range in the same straight line, and would therefore be confused. To meet this difficulty two scales of draft are drawn, at right angles to one another, and the points in the curves are marked

vertically up or down, from the points of intersection of perpendiculars to these two scales at the same draft.

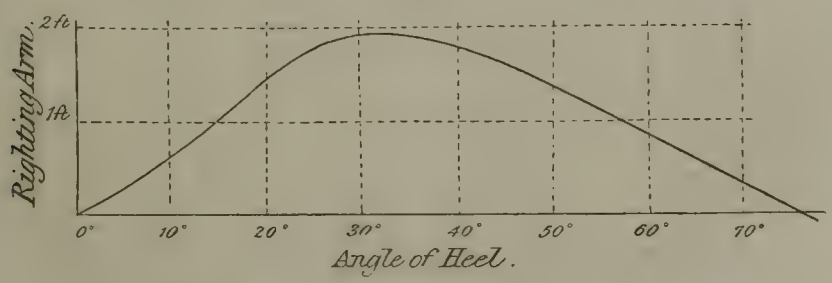
'If the two scales are scales of equal value, as they usually are, the same result is manifestly gained by simply drawing a line at an angle of 45° from the maximum draft (as O to XV in the sketch), and dropping a vertical through that line at any draft for which the height of the metacentre, or centre of buoyancy, has been calculated, and then passing a curve through the points so found. Usually, the curve of centres of buoyancy is practically a straight line, except at the lower part. It is difficult to predicate the form of the curve of metacentres, as its character varies very much in different types of ships; but for ordinary modern cargo-steamers it is usually concave upwards from the base line, and has its greatest values at the lowest drafts. It is, of course, possible to devise numbers of other curves which may be serviceable, but the above are those which are most commonly used, and the data for them are generally calculated, even when the results are not plotted down graphically.

Fig. 16.



'Stability curves (fig. 17), in which length of righting arm is measured vertically, and angle of heel is measured horizontally, are sometimes calculated and plotted, but by no means universally.

Fig. 17.



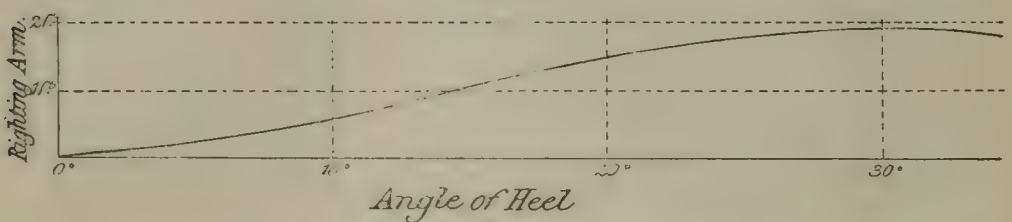
'To be of practical utility they require to be extended by plotting different curves for different positions of the height of centre of gravity, corresponding with different conditions of loading.

'Speed curves, in which indicated horse-power is measured vertically and speed horizontally, are commonly plotted for large passenger and mail steamers, and these are sometimes extended by plotting different curves for varying drafts; but these curves, when based upon mere hypothesis, are not of much practical value, and, as the experimental data for them cannot be obtained without a considerable outlay, they do not occur in *ordinary* practice.

'The curves which I have elaborated most in the foregoing memorandum are those which are most frequently used. They are often combined in one diagram, in a way which will almost naturally suggest itself, but which I need not describe here, as it will be foreign to your purpose. I

have spoken of and sketched roughly the usual *character* of the curves. Of course, this must depend in some measure on the ratio of the vertical and horizontal scales to one another, and I think you would do good service if you pointed out the desirability of some recognised convention as to what this ratio should be for any particular kind of curve. I have myself pressed the importance of this in discussion at the Institution of Naval Architects, but there has been little response. For instance, a stability curve drawn with a ratio in the scales of 1 : 1 is a very different-looking curve from one drawn with a ratio of 4 : 1, and, as will be seen from a comparison of figs. 17 and 18, might be misleading.

FIG. 18.



'The literature of curves is, of course, as scattered as the subjects they relate to. The principles of them are dealt with in almost any work on naval architecture, but their special applications are treated of in Rankine's "Shipbuilding, Theoretical and Practical"; White's "Manual of Naval Architecture"; Reed "On the Stability of Ships"; Thearle's "Theoretical Naval Architecture"; the "Annual of the School of Naval Architecture"; the "Transactions of the Institution of Naval Architects"; the "Transactions of the Institution of Engineers and Shipbuilders in Scotland"; the "Transactions of the North-East Coast Institution of Engineers and Shipbuilders," and "The Proceedings of the British Association," in which some of the late Mr. Froude's most valued papers may be found; and others too numerous to mention.'

Mr. Brodie, the head-draughtsman of the Mersey Docks and Harbour Board, informs me that as a regular thing there are plotted in that office (1) ordinary sections of ground, (2) tidal curves, (3) slopes of tidal surface in the estuary, (4) discharge of pumps under different heads, and pump performances generally, (5) the stresses in various framed structures, (6) engine performances, showing total power and losses on the hydraulic systems of the docks, (7) a number of matters not directly engineering, such as the amount of cotton discharged on certain quays on certain days of the year, the discharge of the dock dredgers in certain places, the capital values of certain property at certain times, the time worked by the dredgers, and time lost in repairs by bad weather, &c.

An interesting case of plotting has been largely employed for the work in the estuary of the Mersey, in connection with a new sounding-machine devised by Mr. Sutcliffe, one of the engineers of the Docks and Harbour Board at Liverpool. This apparatus was designed with a view to the carrying on of an extensive system of soundings at and about the river-entrances to the New North Docks at Liverpool, and its use there proving to be so advantageous that it has been matured and modified to meet the general requirements of river and coast work. By its means soundings can be taken very accurately, and with much less labour than is possible by any other existing means. It admits of sound-

ings reduced to any datum level being obtained direct, and without any calculation. And it enables the operations of taking soundings and plotting the same to be performed simultaneously and by one person.

The apparatus consists of a sounding-machine, a distance-recorder, and a section-plotter. The sounding-machine consists of a wheel with a spiral reel attachment; around its periphery is wound a wire by which a lead is suspended, and the spiral reel carries a preventer line, one end of which passes through a leading-block fixed at the forward end of the boat on which the apparatus is mounted, and thence it is taken back to the lead, to which it also is attached. A wheel and reel are employed so proportioned relatively to each other and to the base that they both pay out or take in the required amount of their respective lines to maintain the lead vertically under the after-end of the base line at all depths of its range. The wheel is 10 feet in circumference, and its rim is divided into feet and tenths of a foot. One end of its axle has a sleeve-bearing, to which are attached a long pointer and a short one, the longer pointer to indicate readings on the rim of the wheel, and the shorter one to show the reading on a fixed disc which is marked similarly to the wheel.

The section-plotter consists of a paper feed-roll, actuated so that the travel of the paper represents to the required scale the paying out of the distance wire. A block, sliding in guides, carries a marker across the paper at right angles to the line of its travel; it is actuated by a cord from a small barrel clamped to one end of the axle of the sounding-wheel, capable of being turned about the same for adjustment, and so proportioned as to indicate, on the required scale, the rise and fall of the lead by the motion it imparts to the marker.

The plotting of the soundings is effected by simply tapping the marker —which is kept clear of the paper by a spring—each time the lead is felt to touch the bottom, and thus there is produced a dotted section to a trial datum, from which, and from a tide-gauge record, the true datum line may be plotted, time having been noted at each end of the line. The position of cross-sights, bearings, &c., may be indicated by holding the marker in contact with the paper while the lead is being raised, so as to produce a vertical stroke, the particular mark so obtained being designated by a note written against it.

Mr. F. G. Baily, B.A., A.Inst.E.E., has kindly furnished the following notes on the plotting of curves for practical electrical work:—

'In the science of electricity and in the practice of electrical engineering the employment of graphic methods is very general. The curves may be used as the numerical interpretation of calculated formulæ, or as a means of giving in a connected form the results of a number of experimental data which frequently are not amenable to mathematical treatment, and cannot be embodied in algebraic form.

'One of the earliest and simplest examples of the latter use is the representation of the magnetic field of an electro-magnet or permanent magnet by Faraday's lines of force, and the method has been greatly developed of late years in the researches on powerful magnets, and in dynamo-electric machinery.

'In connection with this a very important curve of the magnetic properties of metals has formed the subject of much work, carried out principally by Rowland,[1] J. Hopkinson,[2] and Ewing,[2] and the results

[1] *Phil. Trans.*, May 1873. [2] *Ibid.*, 1885.

are given in a curve showing the relation between the magnetising force, H, and the resulting induction, B.

'The same curve continued through a complete cycle of positive and negative magnetisation gives the value of the hysteresis of the iron, and the variation of this quantity with the induction is plotted in another curve.

FIG. 19.

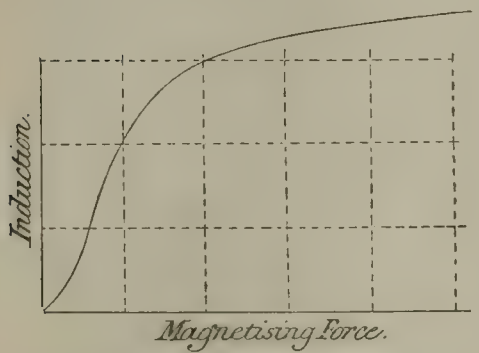
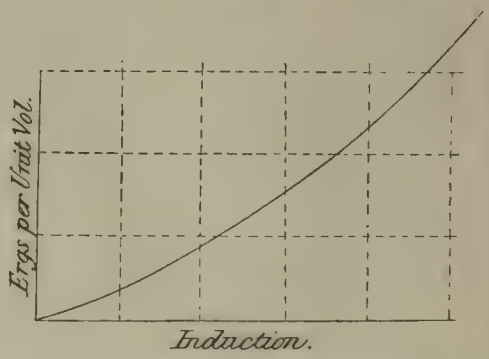


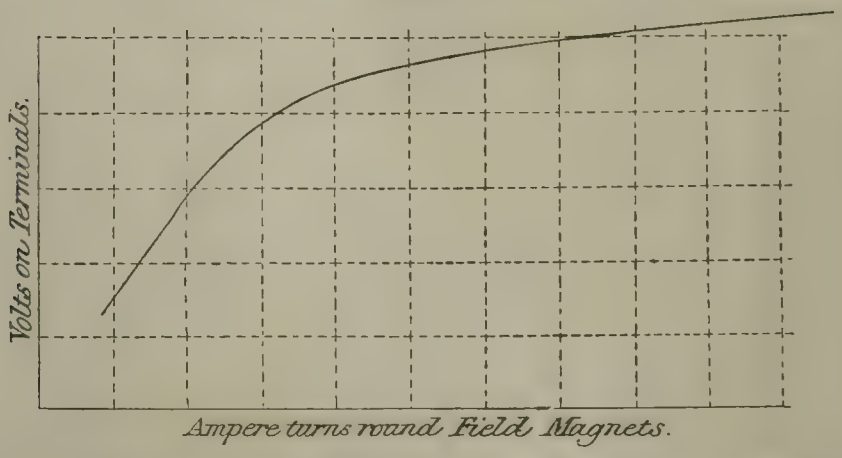
FIG. 20.



'These two curves give the whole magnetic properties of iron, and hence are in constant use in all calculations of electro-magnetic machinery, the more so as they have not been reduced to a convenient equation for mathematical treatment.

'One of the most important curves in connection with this is the characteristic curve of a dynamo, as drawn by J. and E. Hopkinson.[1] The relation between the difference of potential at the terminals of a dynamo running at constant speed, and the exciting current round the field magnets, is plotted as a curve (fig. 21), and they show how, from a

FIG. 21.



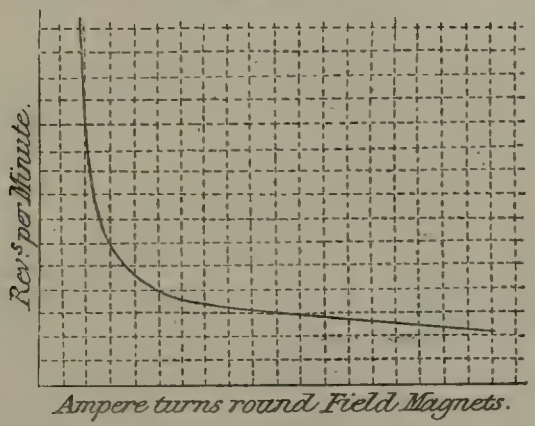
knowledge of the curve of magnetisation of the iron and the dimensions of the machine, the shape of the curve may be foretold with considerable accuracy. When developed in a third direction, representing the current flowing through the armature, a surface is obtained showing the complete behaviour of the dynamo.

'Curves are of the highest importance in the manufacture of dynamos,

[1] *Phil. Trans.*, 1886.

both by indicating where improvements may be made, and in facilitating the design of new types. By their means also several problems, such as the limiting speed at which a shunt-wound motor will excite itself, are readily solved. Besides the characteristic a large number of other curves are in more or less use in dynamo and motor design, such as the curve showing the relation between the speed of rotation of a motor and the exciting current round the field magnets, when a constant difference of potential is maintained at the brushes. The speed being the reciprocal of the effective induction through the armature, the form of the curve (fig. 22) is a combination of a rectangular hyperbola with the characteristic of the machine, the saturation of the iron modifying the hyperbolic form as the exciting current rises.

FIG. 22.



'Various problems in electro-magnets, as regards their attractive force, may be solved and the results rendered clear by this method.[1]

'In investigations on alternate-current machinery the graphic method is largely used. The value of the current varying as to time necessitates a more or less complicated expression. When the current follows a simple law it may readily be treated analytically, but, owing to the effect of induction in the circuit, in practice the law becomes very complex. If, as is generally the case, any part of the field in the neighbourhood of the dynamo or transformer coils or of the external circuit contains iron, the expression for the induction will be a function of the value of the induction of the iron, and this cannot at present be expressed in an equation in terms of the current alone. Hence we are forced to obtain the values of the current at each moment experimentally, and we can only make use of them by constructing the curves connecting the values of the current and time. Many such curves have been made, and show curious deviations from the simple law (fig. 23).[2]

'By another application we may plot the variation in phase between the current and the impressed E.M.F., and the changes produced by the introduction of condensers and choking coils into the circuit. The use of these curves, even when hypothetical, is shown in Professor E. Thomson's explanation of electro-magnetic repulsion.[3]

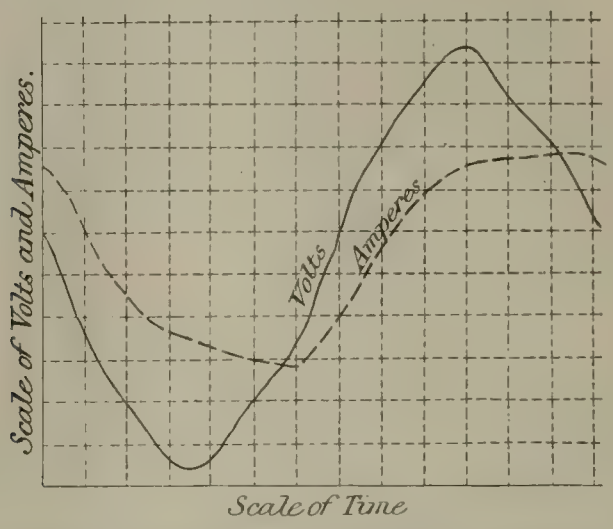
[1] Jenkin, 'Transmitting Power of an Electric Friction Clutch.' *Proc. Inst. C.E.*, vol. cii.

[2] J. Hopkinson, *Electrician*, June 24, 1892.

[3] *Electrical Engineer*, New York, 1887.

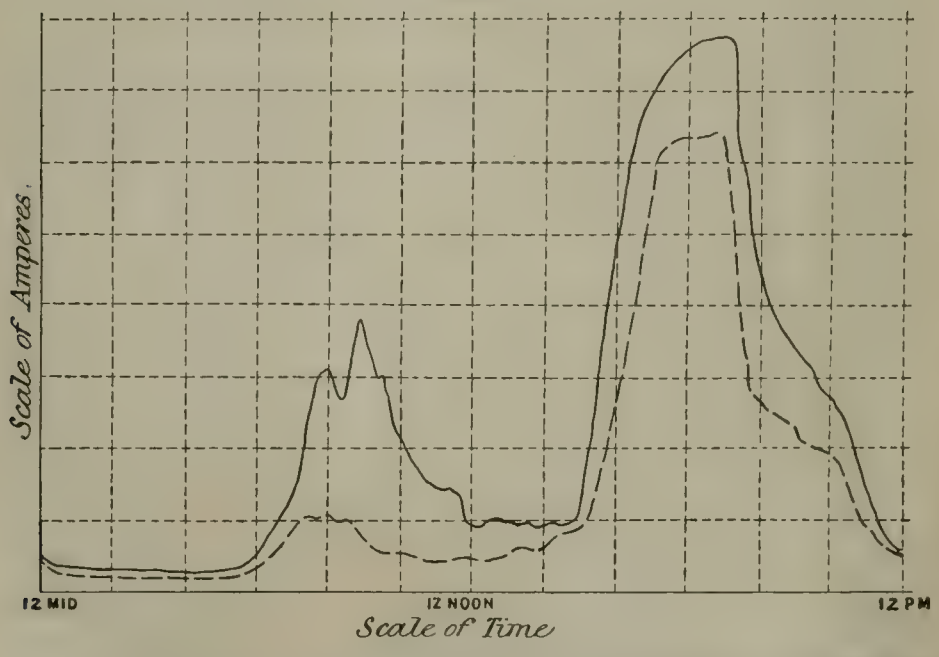
'Dr. Frölich obtains the curves and renders them visible by means of a mirror fixed to a soft iron diaphragm, and caused to vibrate vertically by

FIG. 23.



the current. The horizontal motion is given by reflection from a set of revolving mirrors, and a spot of light passing from them to a screen traces the curve of the variation of the current.

FIG. 24.

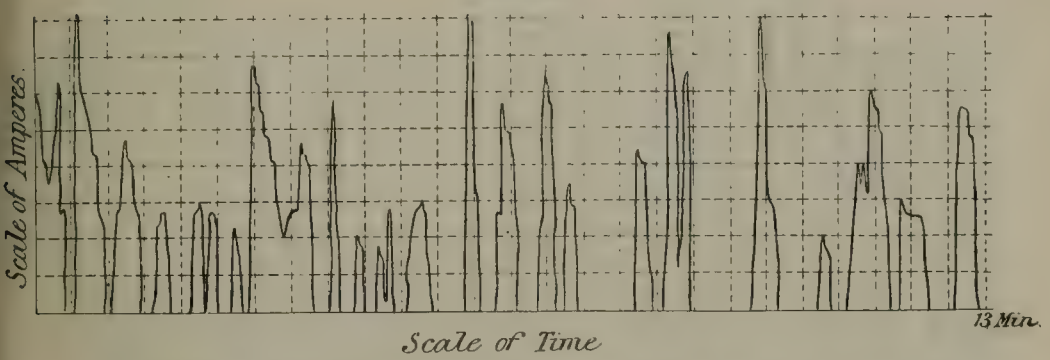


'A development of graphic methods for commercial purposes has been recently brought into prominence in the plotting of the output of central stations for supplying electricity to towns, giving the "load diagram." For this purpose the output of the station with respect to time is made into a curve showing the annual variations in the consumption.

'Some load diagrams for each month of the year in the Berlin central stations are given by Professor G. Forbes.[1] They show the output of the station and the various components in the cost of working. The importance of this knowledge is demonstrated by Mr. Crompton,[2] and in his paper, and in the report of the subsequent discussion, are a large number of examples of curves rendering observed data more intelligible. From the shape of the curve may be deduced what is the most economical size for the units of the generating plant, and, if direct currents are used, the best combination of dynamos and accumulators. Other useful curves are the variation in the coal consumption, and the variation in the cost per unit of electricity according to the time of year and the nature of the district; and the latest development in this line is the use of curves in the reports of public companies instead of tables of statistics. These are drawn to show the operations of the year and the increase of business.[3]

'The curves of the current used on an electric tramcar or locomotive are very curious, and demonstrate clearly the exceptional nature of the work required of the motor and supply stations, or batteries. Several examples have been given by Mr. Reckenzaun (fig. 25).[4]

FIG. 25.



'A similar set of curves has been prepared, by Mr. A. Siemens, of the power used on the locomotives of the City and South London Electric Railway, presented at the present meeting to the British Association.

'Curves of the efficiency and candle-power of incandescent and arc lamps have given valuable information on the most economical way of using them, the most usual form being the relation between the candle-power and energy absorbed for different current strengths, and the variation in the quality of the light.[5]

'Experiments on the output and efficiency of primary and secondary batteries are usually shown in the form of a curve giving the variation in the E.M.F. with respect to time for various current-strengths[6] (fig. 26), and variations of E.M.F. with different strengths of electrolyte.

[1] *Proc. Inst. E.E.*, February 1889. [2] *Proc. Inst. C.E.*, April 1891.

[3] Report of Second Annual Meeting of City of London Electric Lighting Company.

[4] *Proc. Inst. C.E.*, March 1892.

[5] A. P. Trotter on 'The Electric Arc' (*Proc. Inst. C.E.*, April 1892); and see a Report on Glow-lamps (*Electrician*, July 1892).

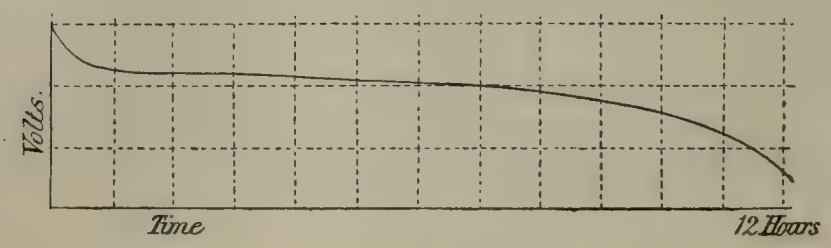
[6] Ayrton, 'Secondary Batteries' (*Proc. Inst. E.E.*, July 1890); Gladstone and Hibbert, *Proc. Inst. E.E.*, May 1892.

'As a means of calibrating an instrument and preparing the scale the graphic method is very largely used. Several points on the scale throughout the range are carefully noted, and the scale-readings in terms of degrees are plotted in a curve. From this curve the position of standard points—10, 20, 30, &c.—are read off without the trouble of exact adjustment of the current or E.M.F. to these values.

'Tables of corrections for instruments are most conveniently arranged as a curve when they are small.

'Though these curves are usually plotted by hand from the results of experiment, the instruments may be made to give a continuous record on

Fig. 26.



a moving sheet of squared paper. Voltmeters and ammeters for this purpose are made by MM. Richard Frères, and are in general use in central supply stations, serving as a check on the intermittent readings of the other instruments, and indicating the degree of watchfulness on the part of the attendants, where a constant current or constant difference of potential is required. Mention may also be made of Professor Ewing's magnetic curve-traces presented at the present meeting of the Association.

'It will thus be seen that the use of graphic methods is very general in the practice of electrical engineering, and the range of its applicability is considerable. In fact, in many cases it is the only available means of utilising and drawing deductions from experimental data, and in all cases it is a great help towards a clear comprehension of observational results.'

Mr. Malcolm Walker, late manager of the 'Sanogen' Ventilating Company, Liverpool, employs in the regular course of his practice a method of plotting for determining the efficiency of hydro-extractors in which a jet of water is used in order to exhaust the vitiated air from a building. Fig. 27 is a specimen of a curve taken from such an apparatus, and enables the efficiency of the arrangement to be at once determined.

It will there be seen that the pressures of water used for the jet are used as abscissæ, and the quantity of air abstracted as ordinates. In another case the same principle is employed when a fan is used, the number of revolutions forming the abscissæ, and the air extracted the corresponding ordinates (fig. 28). This also enables the efficiency of the contrivance to be at once seen, and the proper speed at which the fan should be worked. These observations are made regularly twice a year. Mr. Walker also plots regularly every two months the installation, resistance and deterioration of electric surface, fig. 29 being an example of the curves obtained.

FIG. 27.—Weight of Water in Pounds.

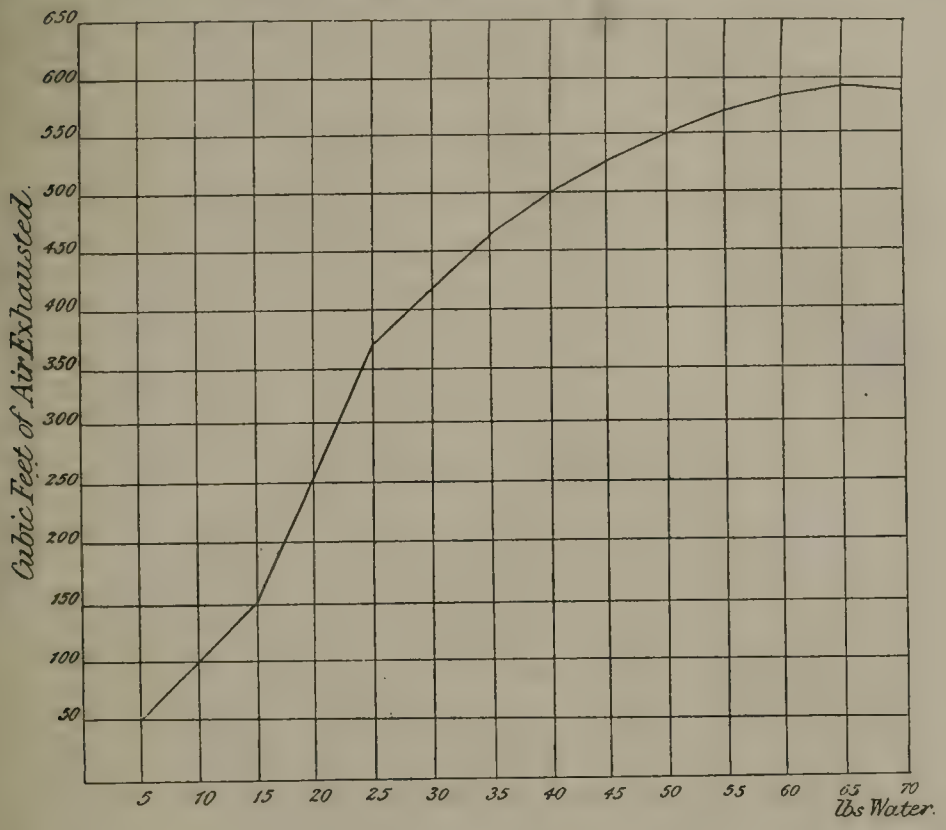


FIG. 28.—Time in Minutes.

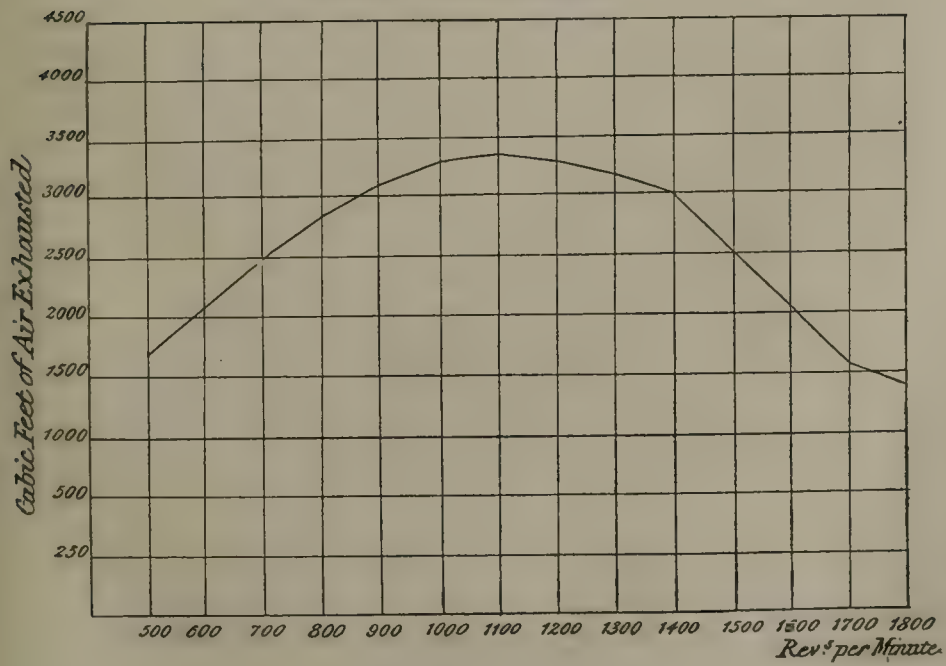


FIG. 29.—Time in Months.

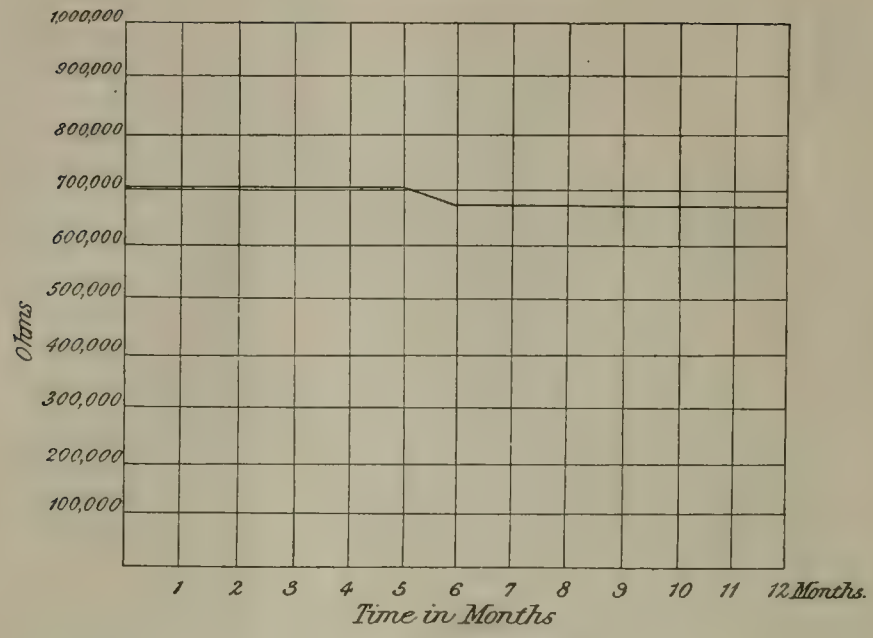
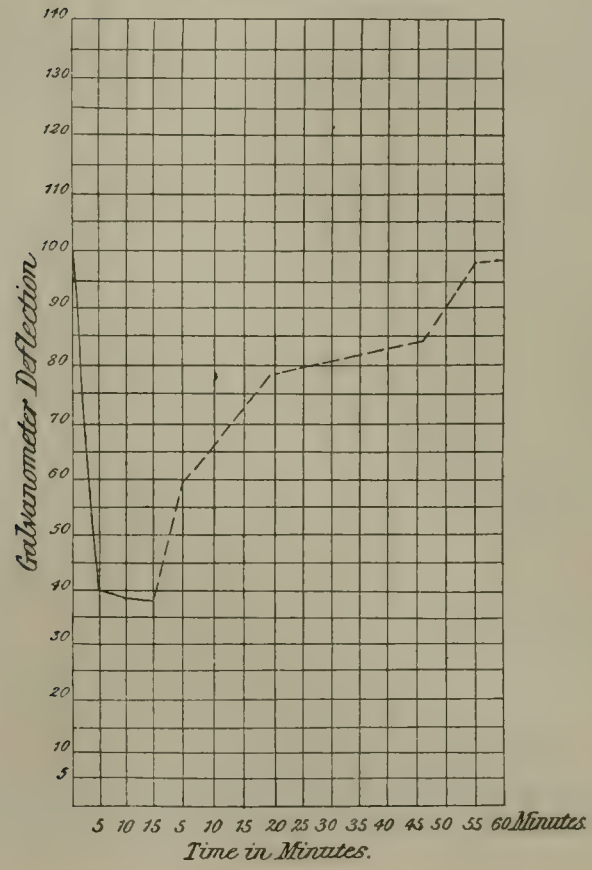


FIG. 30.—Time in Minutes.



Another example of plotting, which the writer believes to be novel, is the fall of polarisation of batteries used for telephones, &c., and the gradual rise of electro-motive force afterwards, as shown in fig. 30.

This has in one or two cases led to the discovery of the cause of failure in telephonic arrangements to be due to the batteries, and not to the telephone, as was at first supposed.

Before leaving the subject of plotting diagrams, it would be as well to remark that the examples which have been given must necessarily be but a small proportion of the cases which might be cited. Thus, in many treatises in which graphic representations are given the action of forces, such as diagrams of bending moment, shearing force, moment of inertia, velocity, efficiency, &c., which may be calculated graphically, is frequently calculated by numerical methods, and afterwards merely plotted, so as to present the results of calculation in a graphic form.

2. *Instruments for Drawing Known Curves.*

The use of the ruler and compass for drawing known curves is postulated in Euclid, and they still retain the place of honour, as by far the most important instruments of the kind in graphic methods.

It is often required to draw a straight line, without using a ruler, with indicator diagrams, and for other work, and then some form of straight-line mechanism must be used. A valuable amount of information on the subject is to be found in the treatises of Professor Goodeve,[1] Professor MacLay,[2] Mr. Kempe,[3] and Professor Kennedy.[4]

In an article by the late Professor H. J. S. Smith [5] in connection with the Collection of Scientific Apparatus of 1876, the following improvements in recent years in compasses are noted:—

1. The arrangements adapted for very fine work, and known as hair-compasses, needle-point compasses, and spring-dividers.

2. The proportional, or reducing compasses, by which we are enabled to reduce or augment in any given ratio the distances which we transfer from one drawing to another.

3. The triangular compasses, by which the position of three points forming a triangle can be transferred from one drawing to another, and which thus serve as an instrument for transferring angles.

4. The beam-compasses, consisting of a beam or bar along which the two points of the instrument may be moved backwards and forwards, the distance between them admitting of adjustment with great precision by means of a micrometer screw.

With regard to the other instruments for drawing curves he remarks:—

'It is by no means an easy matter to invent a good method of tracing a curve. Even when the theory of a curve is pretty well known, that theory may fail to suggest any mode of describing it mechanically; and not every mode which theory suggests can be made to work accurately in practice.' He afterwards mentions elliptic trammels

[1] *Elements of Mechanism*, by Professor Goodeve. Longmans, Green, & Co.
[2] *Mechanical Drawing*, Part I., 'Loci,' by Professor A. MacLay, B.Sc.
[3] *How to Draw a Straight Line*, by A. B. Kempe (*Nature* Series).
[4] *Mechanics and Machinery*, by Professor A. B. W. Kennedy. Macmillan & Co.
[5] *Handbook of the Special Loan Collection of Scientific Apparatus*. Chapman & Hall.

and certain other elliptic compasses, and the conicograph of Dr. Zmurko, of Lemberg, which describes all three conic sections.

Since the above date there have been several improvements in instruments for drawing ellipses, amongst them the conograph, which is the invention of Mr. A. C. Campbell, of Bridgeport, Conn., U.S.A., described in the book of Professor MacLay abovementioned, an account of which is contributed to the 'Transactions of the American Society of Mechanical Engineers,' vol. viii. p. 145.

The most important of recent contributions on the subject of elliptographs is that by Professor Alexander and Mr. A. W. Thomson.[1] The authors mention three modes of generating the ellipse—by (1) a point fixed to the body with two or more studs, and oscillating in straight slots; (2) a point rigidly fixed to a circular wheel, rolling inside another of double its diameter; (3) a point describing an antisatellite motion of double angular velocity round another describing a circular orbit.

The first is, of course, the old elliptic trammel; but they have designed an important improvement, to obviate the objection in the ordinary arrangement of the impossibility of obtaining with the ordinary pen a clean line of uniform thickness, since the pen gets broadside at certain parts of the curve. Their arrangement consists of a steering-needle, which always forms the normal to the ellipse being generated, the principle of a circle rolling in another twice its radius being employed to attain this result.

The second improvement they mention is an example of the anti-satellite method of describing an ellipse, which is used for teaching purposes in connection with Rankine's 'Method of the Ellipse of Stress.' This arrangement, which is used on a blackboard, consists of a T-square pivoted to the board at the butt, and a pointer pivoted to the blade of the T-square. At the back of the blade, where the pointer is pivoted, is a wheel fixed, on this wheel an endless chain is wrapped, which passes round a wheel fixed to the board at the point where the butt is pivoted; hence, if the blade of the T-square is turned to the right, the pointer automatically turns to the left, so that the bisector of the angle between the pointer of the blade is always vertical. By this arrangement the end of the pointer describes an ellipse.

They next describe an improved elliptograph, for continuously describing an ellipse of every eccentricity, by means of a wheel rolling in a circular rack of twice its diameter. The circular rack may be dispensed with if a gauged endless chain wrapping round two wheels is used. Further modifications are also shown, one designed by Mr. Yeates, which is a frame in the form of a ring standing on four legs, armed with prickers to pierce the drawing-board so as to hold the frame steady, and at the same time mark the position of the principal axis. The lower ring, concentric with the other one, runs in four grooved wheels, one in each leg. One difficulty in the construction of this mechanism is to make the lower ring, which runs in the grooved wheels, truly concentric with the cross formed by the slots in the principal ring.

Yet another mechanism is described, in which bevel wheels and a framework form a part, and a steering-needle being always on the radius of what corresponds to the planet in the anti-satellite motion. This

[1] 'Elliptographs,' by Thomas Alexander, M.A., and A. W. Thomson, D.Sc. *Transactions of the Royal Irish Academy*, vol. xxix. p. 673.

instrument works with great smoothness, as, with the exception of the driving bevel wheels, it consists entirely of linkwork. At the end of the paper mechanism is suggested for continuously describing bi-circular quartics.

The actual problems solved by means of the ellipse will be alluded to when dealing with the ellipse of stress and other graphical methods.

The parabola is another important curve in graphical methods, the power of drawing which is indispensable in every problem of bending moment on girders subjected to any uniform or travelling load, and for many other problems. From the fact that all parabolas are similar, it is a simple matter to have parabolic curves of cardboard or other material of various sizes, and, having used whatever size may be most convenient, to find the constants for the particular problem. The authors above-mentioned have designed a mechanism, points in which simultaneously describe parabolas required in problems of bending moment.[1] This mechanism consists of a board, slot frame, compass bars, transverse bar, distance-piece, and distorting-table. As the slot frame moves across the face of the board all points in the mechanism describe the same parabola in different positions. By means of this model bending moment can be clearly demonstrated for any point of the span, whether for a concentrated load or for a load distributed over several points, as in the case of a railway train, either longer or shorter than the span of the bridge or girder under consideration.[2]

Professor H. J. S. Smith mentions the apparatus of Mr. A. E. Donkin for tracing harmonic curves—a machine drawing as many different forms of the curve $y = a \sin(mx + A) + b \sin(nx + B)$ as there are means for varying the constants a, b, m, n, A, B, the number of variations being practically unlimited, except in the case of m and n, which are the number of teeth in certain wheels, which therefore admit of only a limited number of changes.

The most important curves used in the teeth of wheels are the involute, cycloid, epicycloid, and hypocycloid. Practical modes of describing these are given by Professor Unwin.[3]

Another curve which has important properties, and which may be used for the extraction of roots, is the logarithmic spiral; it may also be substituted for table logarithms, as mentioned by Professor Favaro in his book on graphic statics. The same author describes the *gabarit* of Professor Steiner,[4] which is an instrument for facilitating the construction of logarithmic spiral, and may be applied to graphic calculations. The centre of the curve can be marked upon the paper by means of a pricker which passes through a small hole. The apparatus has, according to Professor Favaro, the following uses :—

1. The curve presents a series of curvatures of which the radii cross

[1] *Moment Delineator*, by Professor Alexander, M.A., and Mr. Arthur Thomson, B.Sc. Institution of Engineers and Shipbuilders in Scotland. Read November 19, 1889.

[2] A clear elementary treatment of the use of the parabola in problems relating to girders is given in the *Applied Mechanics* of Messrs. Alexander and Thomson. Macmillan & Co.

[3] *Elements of Machine Design*, by Professor Unwin, B.Sc. Longmans, Green, & Co.

[4] *Leçons de Statique graphique*, par Antonio Favaro. Traduites de l'italien par Paul Terrier. Gauthier-Villars, Paris, 1885.

with continuity, and they lend themselves better than any other form to the juncture between any curve whatever.

2. A portion of a curve being given, one can find rapidly the centre of curvature without using the compass.

3. The development of a given curve can be rapidly constructed without using a compass or rule.

4. Calculations can be readily performed with it.

A very interesting class of modern instruments, called 'integraphs,' has been invented by Mr. Abdank Abakanowicz and Mr. Vernon Boys. These instruments draw what is known as the 'integral curve' when a pointer is passed round the periphery of a figure whose area is required.[1]

3. *Self-recording Instruments.*

There is no class of instruments which have increased to such a great extent as those which record their own results in the form of a curve or mark of some kind. An instrument of this kind may be used for an almost countless variety of purposes, but many of them have certain features in common, or differ in certain important particulars, which enables the subject to be considered under a comparatively limited number of heads.

1. All instruments have some kind of marking arrangement, and some kind of prepared surface on which the record is made.

2. Almost all instruments of this kind have some contrivance for giving motion to the surface upon which the record is obtained, and this motion corresponds to the change in one of the two variable quantities which are to be recorded.

3. The marking arrangement, which makes the record, is actuated by means of some mechanical contrivance so as to correspond in position to the magnitude to the other variable quantity.

These facts supply the headings under which the subject may be studied.

1. The arrangement for marking may consist of—

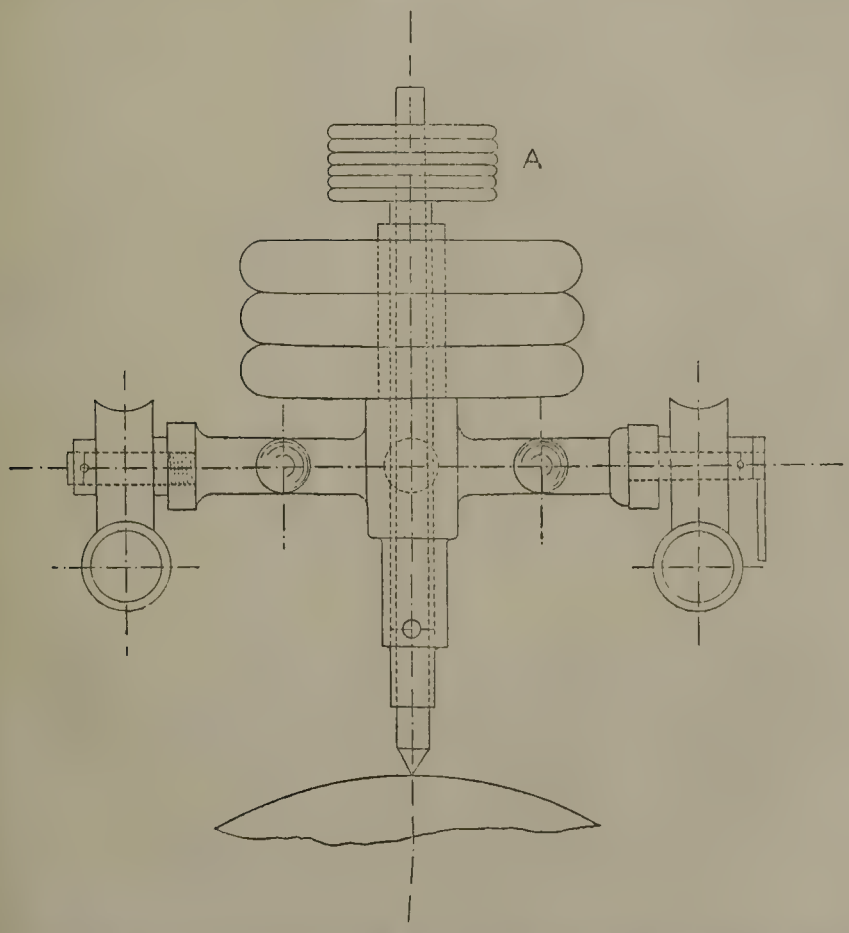
   a. Pricker, which makes a puncture or mark of some kind at certain intervals.
   b. Pencil drawing upon ordinary paper.
   c. Metallic pencil drawing upon prepared paper.
   d. Twisted spiral of one convolution marking the surface in contact with it.
   e. A style scraping a surface of smoked paper or glass, or some other prepared surface.
   f. Pens writing a record with some kind of ink.
   g. Siphon-recorder of Sir William Thomson.
   h. A spot of light reflected from a mirror acting upon a chemically prepared surface.

Of course, nothing but practical results can decide which is the most suitable of all these for any particular purpose, and, from inquiries which the writer has made, it appears that a great difference of opinion exists on the subject.

[1] *Les Intégraphes*, by Mr. Abdank Abakanowicz. Gauthier-Villars, Paris, 1886. 'Integrators,' by C. Vernon Boys, *Phil. Mag.*, 1882.

For indicator diagrams a pencil of some kind is invariably used, generally a metallic pencil, in contact with paper the surface of which is prepared with lime whiting and size. Messrs. Bailey & Co., of Salford, who have a very extensive experience on the subject, prefer aniline pencils, which give an indelible mark, requiring no sharpening, as lead pencils do, and do not necessitate the use of specially prepared paper. Figs. 31, 32, and 33 show the arrangement adopted for a very large level-recorder by Messrs. Bailey; the pencil is here loaded by the small weights (A); the other details will be alluded to hereafter. They consider metallic pencils have too much friction for the ordinary purpose of

FIG. 31.

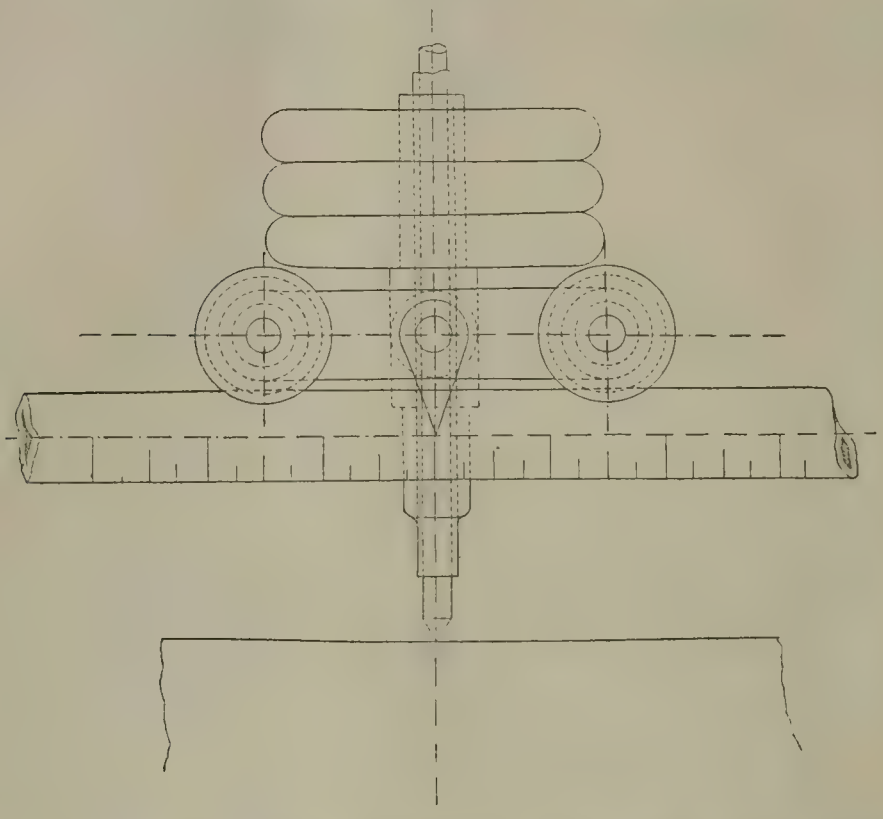


self-recording instruments, while when using some kind of aniline ink they find that the ink dries if placed in the engine-house, where the temperature is above that of the ordinary atmosphere, especially when a record is being made at a very slow rate. On the other hand, when in a moist situation, recording paper becomes damp, and the ink flows too freely upon it, making too coarse a record, rapidly exhausting the supply of ink.

Such, however, is not the experience of another, and probably an equally well-known firm, Messrs. Richard Frères & Co., of Paris and London, who, for the vast number of self-recording instruments which

they make, never use any other means of obtaining records but a small pen supplied with aniline ink, which invariably continues to act for at least twenty-four hours, and will, under favourable conditions, continue at work for weeks or even months. Of course, the composition of the ink used has been the subject of very careful study by that firm, and great

Fig. 32.



care must be taken to prevent pressure with more than the very slightest force against the surface of the paper, or it scrapes up a sort of fur, which soon stops the action of the pen.

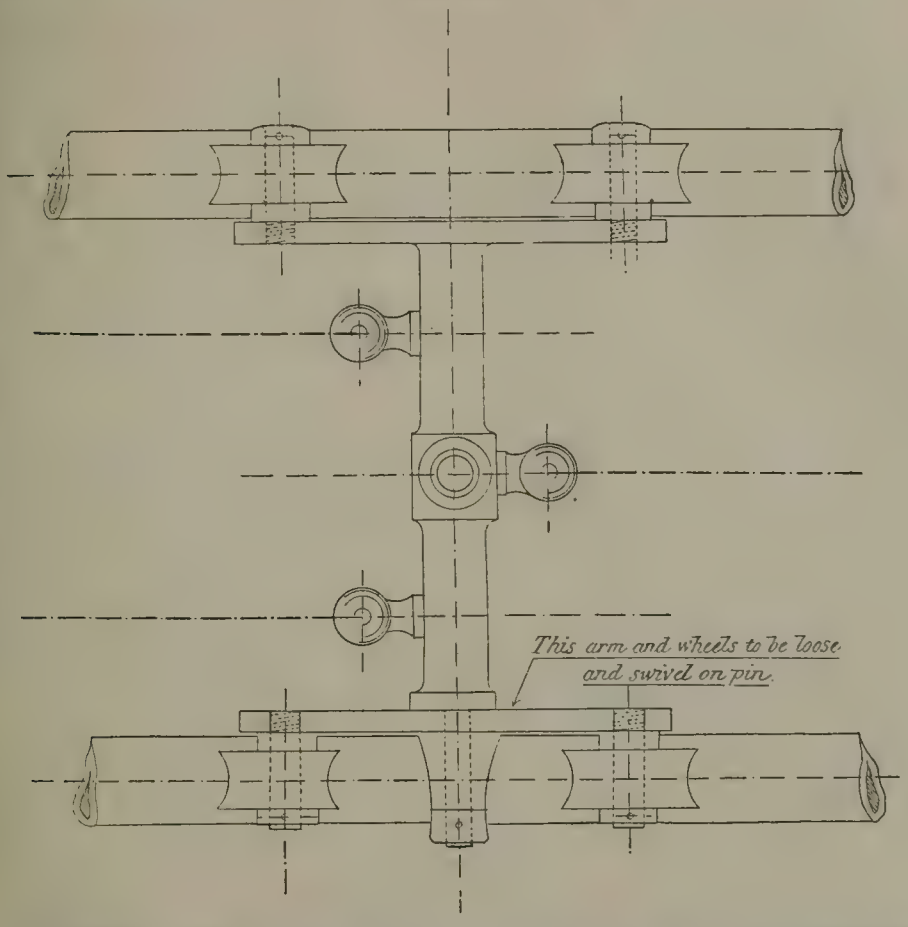
The spiral has been used with various instruments where it is more convenient to turn the marking arrangement about its axis than to move it to and fro; thus, in the self-recording water-meter devised by the writer[1] this arrangement was used, also in the instrument for giving the direction of the wind manufactured by Messrs. Bailey & Co. for the Salford Town Hall. It is clear that the spiral, being in contact with the paper wound round a cylindrical drum, will mark it at any point along the drum corresponding to the angle through which it has been turned. Fig. 34 shows the recording portion of this instrument.

The last two means of recording to be mentioned, viz., *g* and *h*, are the only two which are suitable for obtaining a diagram where it is imperative to have no friction at all at the recording-point.

[1] 'The Measurement of Velocity,' by H. S. Hele-Shaw. *Min. Proc. Inst. C.E.*, vol. lxix. p. 364.

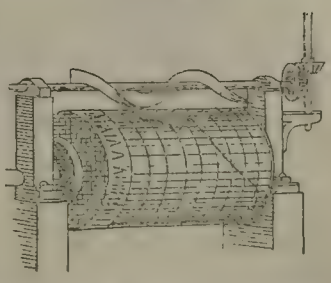
The spot of light is used chiefly in meteorological instruments, as at Kew Observatory.

FIG. 33.



Sir William Thomson's siphon-recorder was invented by him as the outcome of his device for regulating the arrival of an electric impulse through long submarine cables. It was used by Professors Jenkin and Ewing [1] in their experiments on the friction between surfaces moving at low speeds. This contrivance, a small, fine siphon glass, has its shorter end dipped in aniline blue dissolved in water, and the longer has its point bent so as to stand almost touching the surface of the paper. In order to make the ink run through, so as to be deposited on the paper, it is continually maintained in a state of electrification; thus a continuous flow is obtained, forming a fine line, without involving any friction.

FIG. 34.



The kind of paper used for graphic records is a very important matter, and Messrs. Bailey & Co., and others, have found it necessary, to

[1] 'On Friction between Surfaces moving at Low Speeds,' by Fleeming Jenkin, F.R.S., and J. A. Ewing. *Philosophical Transactions of the Royal Society*, vol. clxvii. part. ii.

prevent errors of scale, to have them lithographed with ruled lines. Such paper should always be tested, and, if possible, the actual scale marked on it.

2. Coming now to the means of moving the paper or other prepared surface, it may be said that the almost universal practice is to adopt the cylindrical drum for carrying the record. Moreover, it may be said that in the majority of cases this drum is turned by clockwork, although there is one most important class of instruments in which this is not the case, namely, the steam-engine indicator.

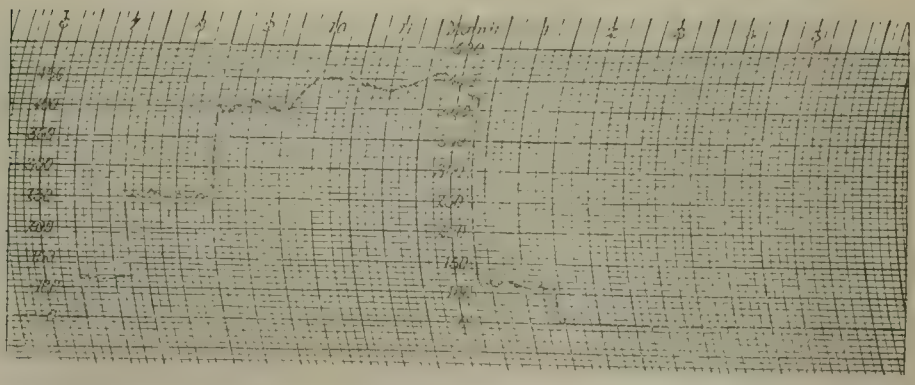
For large instruments—such as tide-gauges, anemometers in observatories—a pendulum or weights are used for giving motion to the barrel, but in the majority of cases this contrivance would occupy too much space, and springs are employed. Continuous papers are frequently used, enabling records to extend over long periods of time, as with the Edson steam-pressure recorder; but the general practice is to have a special chart for each day.

The manner of connecting this chart to the barrel is a matter of no little importance. In the case of the steam-engine indicator the barrel does not turn through a whole revolution, and hence the projecting clips do not present a serious objection; but in barrels which revolve this matter must be provided for, and special precautions are taken by Messrs. Richard, Bailey, and others to prevent injury to the recording-point.

There are some recorders in which a flat surface is used, such as Bristol's recording pressure-gauge, on which a circular sheet of paper is attached to a revolving dial, and the pressures are recorded radially, or nearly so, while time is measured round the circumference.

A special feature of Messrs. Richard Frères' recording instruments is to be found in the fact that the recording-point is almost invariably carried on a lever working about a centre, and hence the paper on their

Fig. 35.



instruments on which the record is obtained has to be ruled in a special manner, an example of which, taken from one of their self-recording ampère meters, is given in fig. 35. A report on the subject of Messrs. Richard's instruments has been given by M. le Colonel Sébert.[1]

[1] 'Notice sur les Instruments Enregistreurs construits par Richard Frères, comprenant le Rapport de M. le Colonel Sébert à la Société d'Encouragement pour Industrie nationale et l'Exposé des Perfectionnements et Applications Nouvelles.'

By having a straight-line motion instead of employing the arc of a circle, the above kind of ruled paper is not a necessity, and the area of the curve, when desired, is more easily obtained. With the larger instruments, such as those of Mr. Bailey, a small chariot is often employed for carrying the pencil, and this runs to and fro on rails above the drum, which is placed horizontally. The chariot itself is loaded, and the pencil, as already mentioned, is also loaded, but with much smaller weights. Figs. 32, 33, and 34 show the kind of chariot which has been largely used in the case of tide-gauges and reservoir-level recorders by Mr. Bailey.

It may be mentioned generally that it has become the custom to always encase such recording instruments; usually a glass front is employed, so that the kind of record being taken can be seen on inspection. Mr. Bailey has found, after much experience, that it is better to use cast iron for the case, as the change of form of wooden cases often led to errors in the instrument.

3. The means by which the position of the recording point is regulated may be made the basis of classification for self-recording instruments, as follows:—

a. Level of water, mercury, or spirit.
b. Pressure of steam, air, or water.
c. Magnetic attractions for electrical purposes.
d. Velocity.
e. Temperature.
f. Vibrations and shocks.
g. Change of position from loss or gain of weight.
h. Chronographs, tell-tales, and similar instruments.

These headings will now be taken seriatim.

a. This class includes various kinds of tide-gauges, reservoir and boiler level recorders, recorders for the depths of wells or record of rainfall, and for the height of the barometer.

A large instrument of this kind, which also records velocity, made by Messrs. Bailey, has been described in a paper by Mr. Hurtzig [1] as follows:

'A ball-float moving in a tube actuates a pencil, which records, on a sheet of paper upon a drum revolving by clockwork, the varying heights of the water, 2 inches on the diagram being equal to a fluctuation of 12 inches of water; the diagram revolves once in twenty-four hours—1 inch=1 hour. For recording the velocity it was determined to register the angular displacements of a spherical ball which, when at rest, was suspended in a vertical position, with its centre coinciding with the centre of the 5-foot culvert. This ball is attached to the long arm of a lever pivoted to a small bracket fixed to the top of the culvert.

'The short arm of the lever is connected by a platinum wire and system of levers, all duly counterbalanced, with a second recording-pencil upon the revolving drum.

'The recording diagram indicates the level and velocity for a period of twenty-four hours. That portion of the diagram referring to level is divided so as to give actual depths of water upon the sill of the sluice, the conditions of the clause requiring that when the depth reaches 4 feet 6 inches, and the sluice doors are closed, pumping must be carried on.

[1] 'Tide-gauge Recorders,' by A. C. Hurtzig, read at the International Congress of Inland Navigation.

'The determination of the divisions on the diagram, and of the angular displacements of the ball, corresponding to certain velocities, were the results of numerous and careful experiments carried out on the old Bolton and Manchester Canal by the makers of the instrument, and Mr. Hurtzig was satisfied that the instrument would give all the information required; and since the date it was erected it has worked well, and is now in perfect order.'

For waterworks such recorders are approximate water-meters, every increase in the height of the water measuring a known quantity (say 1,000,000 gallons for every eighth of an inch rise), so that they form a check upon the water-meters supplying the town.

The late L. J. Crossley, Esq., designed a rainfall-recorder which, though arranged for ordinary purposes, could, during a thunderstorm or sudden downfall, be so altered as to cause the drum to revolve once in an hour instead of once in twenty-four hours by means of a wheel put in gear by a magnet worked from Mr. Crossley's house, more than a mile distant. The matter of distance presents no difficulty in the way of obtaining a continuous record of the height of water in a reservoir or aqueduct; thus, Messrs. Richard Frères make an instrument, designed by M. Grivola, in which only one wire is employed, which may be used to record the level by electric means at any distance.

For short distances, such as about 50 yards, the same makers have an instrument which consists of an iron case, perforated with holes, containing an indiarubber bag filled with air. This bag is connected by means of a copper tube to a self-recording pressure-gauge, and the case is immersed in the liquid. The air pressure, and consequently the height of the liquid, is indicated and recorded by the pressure-gauge, and as there exists no contact between the liquid and the air, the latter cannot get dissolved and the indications are always correct.

The tide-gauge, designed by Sir William Thomson, is well known, and has the peculiar feature of an inclined path for the slider, which holds the recording pencil, necessitating a correspondingly inclined position for the axis of the barrel on which the paper is wound.[1]

A more elaborate tide-gauge has been designed by M. Lechatelier, and made by Messrs. Richard Frères.[2] This is used to record the height of the water in the basin of La Villette.

b. Instruments for recording the pressure of steam, air, or water form probably the most important of all classes of such self-recording apparatus.

First in importance must rank the steam-engine indicator.

The use of this instrument, since the time of its invention by James Watt, has continually increased, and so great has been the attention given to its improvement that a treatise of considerable size might be written on this subject alone. In essential features the instrument remains the same as it was one hundred years ago, consisting, as in almost every recording instrument, of two parts—of a moving pencil and moving paper, whose paths are respectively at right angles to each other. But the introduction of higher pressures and quicker speeds has necessitated numerous but important changes of detail; hence some kind of parallel motion is

[1] The 'Tide-gauge, Tidal Harmonic Analyser, and Tide-predicter,' by Sir Wm. Thomson. *Min. Proc. Inst. C.E.*, vol. lv. p. 2.

[2] *Annales des Ponts et Chaussées*, Mai 1885.

used to magnify the movement of the pencil and enable a small motion of the piston-indicator to suffice, thus avoiding irregularities which would otherwise occur at high speeds in the indicator diagram.

The modified indicator which marked the chief change in the type of the instrument was introduced many years ago to this country from America by Messrs. Elliott Bros., of the Strand, London, and is known universally as 'The Richards Indicator.' The details of other types are given in various journals, mentioned under the title of 'Indicator' in the list appended to this report. The following are the principal makers, most of whom have modifications of their own: Lloyd, Stanley, Darke, Negretti & Zambra, Tabor, Crossley, Maginnis, Schäffer & Budenberg, as well as many others.

Recording steam-pressure gauges are employed for giving, as it were, a history of the pressure in the boiler continuously.

That made by Messrs. Bell consists of an eight-day clock actuating a drum which revolves once every twenty-four hours, the pencil being moved by a treble tube Bourdon steam-gauge.

Instruments very similar in design are made by the same firm for the following purposes: Recording vacuum and hydraulic pressure, and for use in waterworks in connection with pumping engines; for chemical works, to record the dates of absorbing and concentrating columns; and for steelworks and blast furnaces, for recording the blast pressures. They are sometimes made with continuous paper, but this design is not in particular favour, although it is a feature of the Edson steam-pressure recorder. In fact, there are between 2,000 and 3,000 of these instruments in use, representing no less than thirty different varieties of design.

Messrs. Richard Frères also make a steam-pressure recorder of this kind, and there are several other designs, amongst which may be mentioned the Edson steam-gauge recorder, largely used in America.

This instrument, unlike the other two previously described, which were both constructed on the principle of the Bourdon gauge, has a corrugated flexible surface, on which the pressure of the steam acts.

Messrs. Schäffer & Budenberg have made for several years a recording pressure-gauge, although no account of it has apparently appeared in any paper.

Recording aneroid barometers have been in recent years introduced in very large quantities, and every French war-vessel carries such an instrument, records of which are obliged to be always posted with the ordinary log.

The pressure of air in connection with collieries is of very great importance, particularly in connection with the ventilating appliances; and Mr. Joseph Dixon, H.M. Inspector of Mines, feeling strongly on the subject, has been instrumental in getting designed, by Messrs. Bailey, most ingenious mine-ventilating recorders, notice of which appeared in the 'Colliery Guardian.'[1]

Messrs. Schäffer & Budenberg make a hydraulic press recorder which gives several kinds of diagrams simultaneously of the work performed by a system of hydraulic presses during either twelve or twenty-four hours. The diagrams show: (1) The times when the several presses were brought into action; (2) the rate of increase of pressure, and the time occupied in attaining the maximum pressure; (3) the amount of the maximum

[1] *Colliery Guardian*, September 30, 1881.

pressure, and the length of time during which this pressure was maintained; (4) the rate at which the pressure was reduced, and the time occupied in reducing the pressure; (5) the number of times the several presses were brought into operation, and the distribution of the work during the different parts of the day.

A very delicate pressure-gauge by Messrs. Richard Frères is described in the report of Colonel Sébert previously mentioned,[1] which will measure the variation of the water column by a fifth of a millimetre.

Recording anemometers for recording the pressure of the wind also belong to this type of instrument, and one may be mentioned, designed by Mr. Osler, F.R.S., of Birmingham, an example of which is in operation in the Bidston Observatory, near Liverpool, also at Kew and Greenwich. A disc exactly 2 square feet in section is presented to the wind, and the pressure is transmitted to a small carrier, having the recording-pencil attached, in the observatory below, and thus a record is given upon a revolving drum.

The last instruments coming under this class which may be mentioned are the 'stress and strain recorders,' which have now become a part of the equipment of all engineering laboratories, in connection with machines for testing the strength of materials, and it is becoming the practice, in better classes of testing, to take and furnish an autographic record with every specimen tested. The forms of these instruments are numerous, an account of the principal types being given in Professor Unwin's book on the testing of materials,[2] and in a paper by Professor Kennedy.[3] An account of one designed by the writer of this report is given in the 'Minutes of Proc. Inst. C.E.,' vol. lxxxviii. p. 101.

c. Electrical instruments—voltmeters, ammeters or ampère meters, Watt meters, and galvanometers—are all made of the first recording type, and are described in the report of Colonel Sébert, already alluded to, as being manufactured by Messrs. Richard Frères. An example of an ampère meter record has already been given. They are also described and illustrated in the catalogue of the makers, in which the record from these instruments gives everything which is to be known about an electric station continuously, including the times of starting, maximum and minimum production of the electric current, and the way in which the machines have worked.

d. Instruments for recording velocity may be divided into two classes: (1) Those which actually record the velocity by the height of the ordinate on a revolving drum; and (2) those which indirectly do so by the distance travelled over the surface by the pencil in a given period of revolution.

The most common method in which the former acts is by some kind of governor, operated by means of the steam-engine, which raises or depresses the pencil according to the position of the governor balls.

An instrument of this kind, which is now well known, is the 'Moscrop' recorder,[4] and similar instruments have been designed by Messrs. Bailey and Mr. Edson. The application of these instruments has been

[1] *Le Rapport de M. le Colonel Sébert à la Société d'Encouragement pour l'Industrie Nationale*, November 1882, p. 102.

[2] *Testing of Materials of Construction*, by Professor Unwin. Macmillan & Co.

[3] 'Equipment of Engineering Laboratories,' by Professor A. B. W. Kennedy. *Min. Proc. C.E.*, vol. lxxxviii. p. 1.

[4] *Minutes of the Proceedings of the Institute of Mechanical Engineers*, 1884, p. 150.

invaluable, having revealed on various occasions all sorts of defects in the working of the engines, such as insufficient weight of flywheel, flaws in the shafting causing extra friction and irregularity, and imperfect action of the governors. None of these things would probably have been detected except by a continuous graphic record, which, moreover, enabled the defects of the changes introduced to be carefully studied by the diagrams subsequently obtained.

An instrument belonging to the same class, but of entirely different principle of action, has been designed by Messrs. Richard Frères under the title of the 'Cinemograph,' of which a description is given in the report of Colonel Sébert.

An electro-cinemograph for electrically recording the speed or number of revolutions of one or several engine shafts at a distance is also described by the same makers as follows:—

'This instrument is a combination of the speed indicator, previously described, with an escapement system actuated by an electro-magnet.

'It is set ready for work by merely winding up the string of the train of wheels which causes the factors "Time" and "Number of Revolutions" to act upon one another.

'Its installation is effected in the following manner:—

'On each machine a simple electric closing circuit arrangement for each revolution is adopted. To each contact is attached two wires, one of which is connected to a common return wire, the other being taken and connected to a switch placed in the engineer's office. The switches are arranged on a board, in front of which is placed on a bracket the electro-cinemograph. This instrument is connected to the switches as well as to the common return wire, and to a battery placed in the circuit. When the engineer wants to ascertain the speed of any given engine, he, by closing the circuit of the said engine with the switch, immediately sets the cinemograph at work, and obtains a record on the diagram paper of the number of contacts occurring at the shaft in the unit of time; that is to say, its number of revolutions per minute. The speed of every individual motor can thus be controlled.

'This instrument is also used for measuring the speed of water-courses, boats, or yachts by merely connecting it to contacts established on a turbine of the Wolhmann system, or to an electric log of the Fleuriais or other system.'

Instruments for recording the flow and velocity of water have been used, and perhaps the most important is the waste-water meter of Mr. Deacon. This instrument enables any waste to be detected throughout the whole of the system of the water supply of the City, and in a continuous record night and day of the quantity of water passing. It has been fully described in the 'Engineer' and other journals, to which it will suffice merely to give reference.[1]

(2) The principle of the second, or indirect class of velocity-recorders, is to observe the slope made by the line as the pencil travels across the surface moving at a known rate. This is the case with a large number of instruments, in which the revolutions of a turning vane move the pencil over a clockwork drum.

Another well-known type of the Osler anemometer operates on this principle. So also do several kinds of engine-speed recorders; but there

[1] The *Engineer*, Nov. 26, 1886; *Journal of the Society of Arts*, May 17, 1882; *Proc. Inst. C.E.*, vol. xlii. pt. iv.; *Engineering*, vol. xl. 1885, p. 488.

is one which, though adopting the same principle, is very different in appearance and deserves a special mention. This is the 'Cyclometer' of Mr. Ransome (manufactured by Messrs. Manlove, Alliott, & Co., of Nottingham), which gives the time of rotation of any shaft to the $\frac{1}{5000}$th part of a second; and not only is the total time of each revolution recorded, but also the time taken in turning through any minute angle or portion of a revolution may be obtained with equal accuracy. The principle upon which this speed-recorder works is very simple. A cylinder covered tightly with smoked paper is attached to the end of the shaft whose speed it is required to measure. On one side of this drum is placed a tuning-fork of known pitch; one of the arms of the fork carries a small style, which (when the fork is vibrating) oscillates in a line at right angles to the direction of rotation of the drum. When at work the tip of this style lightly touches the smoked paper on the revolving drum, and records on it the number of vibrations which the tuning-fork makes whilst in contact with the paper. It is well known that each vibration must be made in an equal interval of time, the amount of which is known from the pitch of the fork. Thus the time taken in seconds for a point on the smoked paper to traverse one inch will be the number of waves in that inch divided by the number of vibrations per second corresponding to the pitch of the fork used. After the record has been taken the paper is removed from the drum, and the marks are rendered permanent by any thin varnish. The slope of the waves will be a measure of the speed of the drum, but it is easier in this case to count the number of vibrations in a given space.

Under this head is a railway-speed time-recorder used in America. The object of this instrument is to indicate, not only the speed of the train when it is running, but the time at which the train stops, how long it remains still, and the speed at which it has run. The work is recorded upon the paper ribbon, which is divided into minutes and hours, and is put in motion by a train of mechanism controlled by an eight-day time movement, to which it is attached. The motion of the car sets in action a train of gearing, which in turn gives motion to the pencil mechanism, which traverses crosswise of the paper, while the paper itself traverses lengthwise at a uniform speed. The pencil mechanism is put in motion by an eccentric placed upon the axle of the car. A straight line lengthwise on the paper ribbon denotes a stop of the train. The pencil crosses the paper every half-mile the car travels, and from one side of the paper and back again indicates a mile; every fifth mile the pencil travels farther, so as to make the line higher, in order that the miles may be counted up with more convenience, and the work done located with greater ease. This record can be continued for any number of days, the capacity of the machinery and the paper ribbon being sufficient to record eight or nine days by one winding. This ribbon, it will be seen, records the time of reaching and leaving each station, and every part of the work done.

e. Instruments for obtaining an autographic record of the rise and fall of temperature are employed at Kew and other observatories, the level of liquid in the thermometer being continuously photographed. But within the last few years very much more convenient self-recording thermometers have been invented. MM. Richard have designed an instrument of this kind, which consists of a curved brass tube, of rather flat section, hermetically sealed, filled with an expanding liquid. The tube is

placed in a sort of cage, so as to protect it, but at the same time to allow the atmosphere to act upon it, this cage being attached to the box holding the self-recording portion, so that it can be placed in bath-houses, breweries, &c. An instrument acting on a similar principle, which allows a communication with any vessel in which it is desired to register the temperature of the liquid, is also largely used. Still another variety of the same class of instrument acting by means of the expansion of the liquid, is arranged for obtaining the temperature of drying and other enclosed chambers, a rod containing the liquid being inserted in the enclosed space, a self-recording portion being placed outside. Probably one of the most beautiful instruments of this kind is the recording pyrometer designed by M. Saintignon, and described in the report of Colonel Sébert already alluded to. This pyrometer acts upon the differential principle, a reservoir of the water at constant height being placed about 9 or 10 feet above the place of which the temperature is required. The water passes first through a filter divided into two parts, the external compartment being that in which the liquid circulates, and which acts as an envelope to cool the water after it has passed through a hollow tube placed in the oven or furnace the temperature of which is required to be known. It then passes out, acting on the bulbs of two air thermometers, one of which communicates with the outer partition of the vessel above mentioned. By means of a delicate aneroid there is thus obtained a graphic record of the temperature of the furnace.

A hygrometer is also described, composed of two thermometric tubes placed one beside the other; one rests in the dry, and the other is maintained at constant dampness by means of a cotton wick descending into a metal basin by the side of the instrument. The thermometric tubes each have the self-recording pencil marking the same drum revolving by clockwork; the difference between the two records is the measure of the humidity of the air. To this instrument the name of 'Psychrometer' has been given.

A self-recording marine thermometer has been used by M. Pouchet, director of a French marine laboratory, which can be submerged to a depth of 120 feet, being raised every fifteen days for changing the paper of the recording portion. This is also described by Colonel Sébert, being made and designed by Messrs. Richard Frères.

Coming under this head may be classed the various types of sunshine recorders, the simplest of which was designed years ago by Sir G. G. Stokes, Bart., consisting of a sphere which focussed the sun's rays upon a graduated strip of paper, so as to give the intensity of the sunshine at various times. Other and improved instruments of the self-recording type have been since designed for this purpose.

f. In recent years a careful study has been made, by means of self-recording instruments, both of the shocks resulting from earth-tremors or earthquakes, and of the vibrations in locomotives, vessels, and machinery. This work has been done through the agency of various self-recording instruments, which have cleared away a great number of erroneous ideas regarding earthquake shocks and vibrations generally.

Self-recording instruments for examining earth-tremors, or seismographs, have principally originated with the professors who have been fortunate enough to find a field for their labours in Japan, where these phenomena occur so frequently as to give tolerably constant employment to self-recording instruments. Professor Ewing and Professor Milne

have both made important contributions in this direction. In a paper [1] read before the Royal Society by Professor Ewing the principles of seismographic construction are unfolded. The author remarks that the difficulty in earthquake measurements is to find a point which does not move during the disturbance. The bob of a pendulum, if suspended by a spiral spring, remains at rest vertically and horizontally, especially if the pendulum be long and the frame to which it is suspended rigid; but there are two reasons why an instrument on this principle is not efficient. In the first place, the recording portion is not easy to make in a satisfactory manner; secondly, the motion of the point of suspension causes a corresponding motion to be communicated to the bob, which, if the period of earthquake oscillation agreed exactly with the pendulum's free period, would altogether vitiate the result. He then describes a seismograph devised by himself, in which solid cylindrical bobs are pivoted with their axes vertical between steel centres. These centres are carried by a frame, and attached to the frame is a style with a tracing-point, so that when the frame is moved forward by a sudden earth-tremor the inertia of the cylindrical bobs causes them to remain nearly, if not quite, at rest. A plate or recording surface, which is connected with the frame and moves with it, thus receives by means of the style a mark corresponding in magnitude to the intensity of the earth-movement which it is required to record. By placing the two frames carrying the bobs in position at right angles to each other, the components of any horizontal motion can be recorded. This instrument is called by the inventor the 'Astatic Horizontal Lever Seismograph.' Since that time Professor Ewing very much improved his original idea, and reference to papers describing the result will be found in the index of subjects appended to the report. Professor Milne has also devised self-recording arrangements in connection with earthquakes, many records obtained by which, in the grounds of the Tokio Engineering College, having been described by him.[2]

Similar instruments have been used by Professor Milne [3] for studying the motion of locomotives, in which both the vertical and the horizontal motion is recorded, the continuous record being obtained on a band of paper, as on the Gray-Milne seismograph. The authors mention the following types of instruments:—

1. 'For timing trains, and giving general information respecting the condition of a line. This consists of the double-clock arrangement just described, driving a continuous band of paper about $2\frac{1}{4}$ inches broad at the rate of 1 foot per hour. On this band only the vertical motion is written; but inasmuch as lateral jerks have usually a vertical component, these also are in part recorded.

2. 'For giving detailed information respecting a line. In this instrument clocks similar to those of No. 1 are employed, but the band of paper driven by them is broader, and all the components of the motion are recorded upon it. In addition to timing a train and showing irregularities on the line, this instrument indicates curves and gradients, shows when brakes are applied, &c.

[1] 'On a New Seismograph,' by J. A. Ewing, B.Sc. *Proceedings of the Royal Society*, No. 210, 1881.

[2] 'Construction in Earthquake Countries,' by J. Milne. *Min. Proc. Inst. C.E.*, vol. liii.

[3] 'On the Vibratory Movements of Locomotives, and on Timing Trains and Testing Railway Tracks,' by J. W. Milne, F.R.S., and John MacDonald. *Min. Proc. Inst. C.E.*, vol. ciii.

3. 'For testing locomotives and carriages. This only differs from No. 2 in the clockwork, which is arranged to drive the paper at the rate of about 1 inch per second for a short interval of time.'

In the discussion which followed the reading of this paper Mr. Milne explained instruments made by him for the same purpose; Mr. Dawson and M. Kapteyn also mentioned other instruments for a similar purpose. Quite recently an account has been given by Mr. Yarrow, in a paper [1] read before the Institution of Naval Architects, of an instrument, called by him the 'Vibrometer,' for investigating the results of a new method of balancing marine engines in torpedo-boats. This instrument consists of a drum provided with suitable clockwork, and resting on a circular plate. The circular plate is hung by three indiarubber suspenders to a frame, which is rigidly connected with the hull of the boat. The circular plate can slide freely up and down on three guides, and form part of this frame. A pencil or style is attached to the frame, and placed in contact with the clockwork drum. It is clear that since the pencil partakes of any movement of the hull, while the barrel of the circular plate has a free vertical motion, any up-and-down movement of the hull will be recorded on the revolving drum, the axes of which are, of course, vertical. By means of this instrument many important facts concerning the vibration of the vessel were ascertained.

g. Instruments for graphically recording the results of mathematical operations have been frequently designed. In the year 1845 Mr. F. Bashforth read a paper, an abstract of which appears in the British Association report, and which he afterwards further expanded in a pamphlet, and by means of lithographed diagrams explained the machine itself. Concerning the action of the instrument mentioned in the pamphlet [2] he remarks:—

'Persons engaged in testing theory by experiment have frequently derived great assistance from mechanical contrivances, which give rapid and near approximations without the trouble in every separate case of going through tedious multiplications and additions. The proposed machine would be capable of giving the values of $\Sigma\{b \cos (n\theta+a)\}$ or of tracing the curve $p=\Sigma\{b \cos (n\theta+a)\}$, where n is any $+ve$ or $-ve$, integer or fraction. It might be employed to find the numerical roots of equations, correct, probably, to two places of decimals, to trace curves representing the intensities of the different kinds of light in the rings given by polarised light, or to illustrate the effect of the several terms (separately or together) of the value of u in the lunar theory. The accuracy of the values given by this machine would very nearly correspond to those of the slide rule—the first two figures would be correct, the third doubtful.'

Probably the most important instrument of this class is the mechanical tide-predicter, one form of which was constructed for the Tidal Committee of the British Association. In this machine, which has been described [3] by Sir W. Thomson (Lord Kelvin), there are ten shafts, giving respectively the following tidal constituents:—

[1] *Engineering Review*, May 5, 1892.

[2] 'Reprint of a description of a Machine for Finding the Numerical Roots of Equations and Tracing a Variety of Useful Curves.' By E. Bashforth, B.A. Cambridge, Metcalfe, 1822.

[3] 'The Tide-gauge, Tidal Harmonic Analyser, and Tide-predicter.' *Min. Proc. Inst. C.E.*, vol. lxv. 1890.

1. The mean lunar semi-diurnal.
2. The mean solar semi-diurnal.
3. The larger elliptic semi-diurnal.
4. The luni-solar diurnal declinational.
5. The luni-diurnal declinational.
6. The luni-solar semi-diurnal declinational.
7. The smaller elliptic semi-diurnal.
8. The solar diurnal declinational.
9. The lunar quarter diurnal, or first shallow-water overtide of mean lunar semi-diurnal.
10. The luni-solar quarter diurnal shallow-water tide.

It has a hanging weight, consisting of an ink-bottle, with a glass tubular pen which marks the tide level in a continuous curve on a long band of paper, moved horizontally across the line of motion of the pen by a vertical cylinder geared to the revolving shafts of the machine.

An instrument of a similar kind was afterwards constructed by Mr. Roberts for the India Office, and it was estimated that, by moving the handle up and down through the range of a semi-diurnal tide in two seconds, a year's curve could be produced in twenty-four minutes. But this is, however, ten times the speed to which the mechanism actually in use limits the practical working of the India Office instrument. Sir W. Thomson has therefore designed a third tide-predicter, which he describes in the above paper, the general principle of which is therein represented in an engraving.

h. There are a variety of self-recording instruments which are employed for chronographic purposes, such as giving the time of opening the door of a furnace, or of charging a blast furnace, or of the passing of a railway train, or of the period at which a watchman passes a certain point. These are sometimes operated by direct mechanical action, as in the watchmen's clocks invented by Mr. Bailey. One of the best of these is an invention by Mr. F. M. Pratt, described in the 'English Mechanic.' These tell-tales are employed for controlling the watchmen of works, hospital nurses, timekeepers of factories, inspectors of police, weighing-machine men, gaswork stokers, stablemen (that it may be seen what time the stable had been opened), domestic servants (to ascertain what time they got up), fire brigades (to see what time the alarm-bell was rung), scavenging superintendents, bank porters, dock warehousemen, prison warders, gatekeepers, &c.

Mr. Burke has invented a watchman's watch, which is made by Mr. Bailey, and acts upon the principle of a mark being made on a recording drum, to do which a key must be inserted, which can only be obtained at each station which the watchman has to pass. Several different types of recorders in connection with the time and movement of engines in mills and factories are also made by Mr. Bailey. Instruments of this kind are frequently actuated from a distance by means of an electric current. Messrs. Richard Frères make a controlling chronograph in which an electro-magnet, carrying a pen, traces a continuous line. Every time the process under observation closes the circuit and establishes a current, the pen traces a vertical line, and the duration of the process, as well as the exact moment at which the marks are made, are given by the diagram.

It will be seen that among the self-recording instruments mentioned are anemometers, barometers, chronographs, hygrometers, dynamometers,

speed-recorders, hydrometers, meters of all kinds, pressure-gauges, pyrometers, tide-gauges, thermometers, ammeters, volt-meters, galvanometers, and chronometers. This is a tolerably comprehensive list, and a large number are also referred to in the accompanying appendix to this report; yet it is impossible to do full justice to the subject. Various instruments by probably the two most important makers, Messrs. Richard Frères, the French firm, and Mr. Bailey, of Salford, have been referred to, as well as those of others, but a very large number of such instruments have been designed and made of which the writer is obviously unable to ascertain any details or give any notice. There are also numerous instruments made by the above makers of a compound nature, recording several operations at once, which scarcely come under any classification, such as instruments for exhibiting at one view time, pressure, speed, and temperature connected with an engine, instruments for giving a weekly diagram for speed, and pressure instruments for recording the number of checks and the time given in by workmen.

III. Solution of Problems.

The solution of problems by graphical methods, that is to say, by geometrical construction, has two aspects :—

1. The use of known curves or simple plotted figures for problems, which are well understood, and have become part of the subject-matter of all engineering pocket-books. The drawing of such curves has already been dealt with, and the increasing employment of 'graphic' tables mentioned. Matters which a few years ago were questions of theory only have now been placed by the light of experience in the catalogue of cut-and-dry facts which can be plotted graphically. Take, for example, the subject of girders and rolled joists. A few years ago each girder was a subject of separate calculation by the engineer designing a structure. To-day, makers of such girders send out lists giving the sizes of girders and all their proportions (including price) for the various conditions of loading found in practice, and such lists can be, and often are, put in a graphical form,[1] and the engineer or architect, if he chooses to trust such a table, has only to refer to it and select a suitable girder for his work.

Again, take the case of marine steam-engines and boilers. Here many of the Board of Trade rules have apparently reached a final form for cranks and crank-shafts, boiler-plates, stays, tubes, safety-valves, &c., and might be thrown into graphical form for practical use.

Now the use of plotted tables is really an expeditious mode of graphical calculation, because even the interpolation of a value, which is generally required, and the use of a scale for measurement, is practically a graphical process, and is clearly to be distinguished from the construction and drawing of such a table from given numerical data. For this reason some remarks are made upon the use of such tables in this division of the subject; and for the same reason, under the same heading, the subject of slide rules is also considered.

2. But in mechanical science, whatever may be the results hitherto attained, problems are always arising which require solution, and even in the face of achievements such as the Forth Bridge, the Eiffel Tower.

[1] A number of examples have been already given (*see* p. 388).

the recent large span-roofs of large stations and exhibitions, the gigantic floating machines of our navy, the St. Gothard, Mont Cenis, and other tunnels, no one will be found to dispute the fact that the unknown in practical science is greater than the known. Thus we have Poncelet saying, in words which are quoted by Culmann in the first edition of his work, 'Die Graphische Statik,' 'What are we to do with all those theories which have arisen in the various branches of engineering that are capable of scientific treatment; which theories, though enabling us to solve some certain problems, at a great expenditure of time and trouble, are far too tedious to be applied to any and every case occurring in practice, and, for the same reason, are not even suitable as a basis on which to work out ready-calculated tables?' and proceeds further to remark: 'This question, no doubt, was in Poncelet's mind when he endeavoured to invent geometrical solutions for the various problems presented in engineering.

'And, in fact, the constructing engineer will give preference to geometrical solutions wherever an accuracy of results up to three decimals (one-thousandth), which can be perfectly well obtained, is sufficient; for his drawing-instruments are always at hand. Drawing is his habitual expression of thought—"his language," and, thanks to his topographical and geodetical training, he is more accustomed to judge as to the exactness of sections, and to define lines and points with great precision, than the architect or mechanician.'

'Poncelet's solutions were, invariably, mere conversions of previously evolved analytical terms. No doubt Poncelet himself felt that this was a roundabout way, and that a geometrical construction will much less readily impress itself on the mind if, in applying the same, it is necessary to bear in mind an analytically developed formula, the derivation of which, probably, has meanwhile slipped our memory, than if the configuration of lines presented by the problem does in itself form the basis from which the solution may be evolved on purely geometrical principles. It was for this reason, probably, that he devoted himself industriously to the study of geometry—as if filled with a presentiment of the great use which the study might afford him. But it was in exceptional instances only that he applied geometry for the solution of statical problems in the architectural branch, while otherwise he invariably preferred analytical solutions, which he subsequently "converted."'

These remarks of Culmann have been quoted at length because of the prominent position which he occupies as an exponent and advocate of the purely geometrical method of treating graphical problems, and are well worthy of careful consideration.

They incidentally contrast the two lines of operation, viz.:—

a. The analytical method;

b. The geometrical method;

upon one or other, or a combination of which, workers in different countries, approaching from whatever point of view, have attempted the solution of such problems.

It may at once be remarked that the allusions to the geometrical treatment of problems refer entirely to the representation of forces by lines, and to one branch of such work, viz., statical problems in structures. Hereafter other problems, such as those of dynamics and the representation of velocity, will be dealt with, but for the present the argument refers solely to that branch of the subject known as graphic statics.

Returning to Culmann's words, it will be seen (1) that he is satisfied as to the engineer's innate preference for the use of geometrical construction; (2) that he is perfectly convinced that geometrical methods of solution of such problems are the best; and (3) that he regards the work of Poncelet in using so much the analytical method chiefly as resulting from the want of sufficient geometrical machinery at his disposal.

Now Culmann himself, satisfied not only of the natural readiness of the engineer to use geometrical methods, but of the inherent benefit of purely geometric solutions, found in the growth and development of projective geometry the very machinery he could avail himself of, and which he did, with results best described in the language of a great thinker, whose impartiality is undoubted. Cremona, in a preface to the Italian treatise of Sairiotti on graphical statics, writes :— [1]

'Little more than twenty years have elapsed since Culmann published the first edition of his immortal work, "Graphic Statics," and the treatises and articles which have successively appeared in various parts of the civilised world on the same subject are innumerable. By that work, complete in its kind, the learned professor created a wonderful combination of graphic methods based on projective geometry, and demonstrated that by them the most varied problems of engineering could be solved more simply and rapidly than appeared possible by the use of mathematical analysis.

'For some time both professors and engineers were cool and sceptical as to the promises held out by the new doctrine; either on account of their inveterate faith in the omnipotence of calculation, or because the constructions of projective geometry had not yet become familiar, or, finally, because the work of Culmann itself was not written in a style and form susceptible of superficial study. . . .

'Germany, England, France, Scandinavia, and America were not long in recognising the great efficacy of Culmann's studies. Books more or less elementary were compiled, and courses of graphic statics were established in the polytechnic schools and in other institutions for the education of engineers.'

The views above quoted of Cremona fairly represent those held in Germany, Italy, Switzerland, and perhaps, to a less extent, in France. That they have not taken root in England may be well illustrated by the following extracts from English writers :—

Professor Sydenham Clarke, in the preface of his book on graphic statics,[2] says : —

'The study of graphic statics, as a subject *sui generis*, has made but little progress in England, though the great value of numerous graphic methods has long been fully acknowledged. While in many of the great engineering schools of the Continent the subject is deemed worthy of a professorial chair, in England it is left to be gleaned almost haphazard. A method, more or less, is thrown into a course of teaching, according to the predilection or dislike of the teacher for graphic modes of procedure.'

[1] *La Statica Grafica.* Lezioni dell' ingegnere Carlo Sairiotti, 1888. Ulricot Hoepli, Milan.

[2] *The Principles of Graphic Statics,* by George Sydenham Clarke, R.E., 1880. E. & F. N. Spon, London.

Mr. James B. Chalmers, in the preface of his treatise on the same subject,[1] writes as follows:—

'The following treatise is confined to the more valuable applications of the graphical method, the creation of Professor Culmann, of Zurich. Were a preference for this method once established, it might then in England, as now in Germany and Italy, be built up into a systematic discipline, remarkably fitted to exercise the intellectual powers. Beginning with projective geometry as founded by Poncelet, followed by geometric statics as taught by Möbius, the *Calcul par le trait* of Cousinery, the properties of the Funicular Polygon of Varignon, so remarkably extended and employed by Culmann, and their application to the Elastic Line by Mohr, we should have a course of engineering mechanics so invigorating to the mind that our students, having undergone its discipline, would feel themselves men well prepared for work, capable of appreciating the conditions and reasoning upon the data of a large class of practical questions to which they might require to address themselves.

'From its birthplace in Switzerland, 1860, this method has passed into Germany, Austria, Italy, Russia, and Denmark, where, after Culmann, Wilhelm Ritter, Cremona, Favaro, and many others, have communicated their enthusiasm to their pupils, through whose superior discipline their respective countries may soon rival in engineering fame that of the country which we fondly regard as its cradle, and as its most able instructress.

'The reason we apprehend lies, first of all, in its geometric character. The designs of an engineer are geometric conceptions; his structures are geometric forms, within which forces statically combined act along geometric lines, so that it is natural that he strive to follow a train of geometric thought.'

Still another writer may well be quoted, representing an American point of view. Mr. Jay Du Bois says, in his work on graphic statics:—[2]

'For the practical engineer the importance of graphical methods needs, indeed, to-day no demonstration. Such methods are everywhere in use. But a simple and general system, which shall include all such solutions, and from which they all flow, is, at least in this country, unknown. Even in English literature there is to be found little more than the very elementary deductions of our first chapter, so that it may justly be said that the entire method owes its existence and development to the labours of German scholars, and the enlightened appreciation of German engineers.'

Now it is to be noted that all these are writing, not of the actual solution of problems by graphical means, but on the general adoption of the geometrical basis of approaching such problems, though this is not so clearly indicated as it might be in the first portion quoted of Mr. Chalmers's remarks. Indeed, no one would deny that not only in graphical representation, already dealt with, but in the mechanical treatment of, at any rate, one class of problems, viz., framework, English engineers are in nowise behind, and it is a usual thing in engineering journals in this country for graphic diagrams of stress to be given when illustrating

[1] *Graphical Determination of Forces in Engineering Structures*, by James B. Chalmers, C.E., 1881. Macmillan & Co., London.

[2] *The Elements of Graphical Statics and their Application to Framed Structures*, by Jay Du Bois. 1883. John Wiley & Sons, New York.

a new bridge or roof. Cremona[1] says of this branch of graphical methods, 'No section of graphical statics is more brilliant, or shows more effectually the services that geometry is able to render to mechanics, than the one dealing with reciprocal figures and framed structures with constant load.' It is in the use of purely geometrical methods of reasoning as the bases of graphical construction that the English engineers do not at present claim much interest.

That one or two leading minds have here and there made important contributions to the subject, notably the late Professor Clerk Maxwell in giving the world the theory of reciprocal figures, does not in any way vitiate the general truth of the foregoing remarks.

The fact is, that very few engineers in this country understand even the nature of projective, modern, higher geometry, or geometry of position, by all of which names it is variously called. This is not to be wondered at, since it is scarcely taught at our colleges. Even at Cambridge it has so insignificant a place as to be honoured with only one or two questions in the Tripos. At Oxford the attention devoted to it is a little more extended. Professor Henrici, whose article in the 'Encyclopædia Britannica' places the elementary propositions of geometry clearly before English readers,[2] has always made the subject part of his mathematical course of instruction, but it takes little, if any, part in the course of the ordinary mathematical education of an engineer.

But England does not stand alone in this respect, for the French translators of Culmann's work—three engineers[3]—remark:—

'The reading of this work requires the knowledge of what was termed recently higher geometry, and which is now called geometry of position, or projective geometry. Although this science is not officially taught in our schools, we hope this will not prove an obstacle to the spreading of graphic statics.' And Culmann himself said in the preface of the first edition of his work:—

'We have experienced unspeakable difficulties in securing for the students attending our lectures a possession of the requisite preliminary knowledge, by ensuring that geometry of position was made by the educational authorities an obligatory subject of study. We have lectured on graphic statics as long ago as 1860, yet it was not until 1864 that the students were provided with the requisite preliminary instruction in geometry by means of an obligatory six-months course of lectures.' But he goes on further to remark: 'For the engineer, and for the technical man generally, geometrical instruction is no less important than analytical instruction; he has always to deal with the graphic representation of configurations of space. How useful, then, must it be to him to have his stereographic perception trained and developed to a certain extent, thus enabling him to resolve with ease plane projections into solid bodies, and to conceive in his mind a stereoscopic view of the whole work of construction or machinery which is to be executed. How much more progress might be made in graphic geometry,

[1] Preface to English translation of *Le Figure Reciproche nella Statica Grafica* (L. Cremona, Milano, 1870), by Professor T. Hudson Beare. Clarendon Press, Oxford, 1890.

[2] The excellent translation of Cremona's *Geometria Progettiva*, by Mr. Charles Leudesdorf, M.A., Clarendon Press, Oxford, should also be noted.

[3] G. Glasson and J. Jacqmer, Ingénieurs des Ponts et Chaussées, and A. Valet, Ingénieur Civil.

or at least in geometry of situation, if the student could treat the first named as a special application, to a given case of the latter; how many superfluous definitions and demonstrations would be spared to the lecturer if they had already been grafted into the student's mind, so as to be completely mastered by him, as parts of a more comprehensive whole!'

This subject is thus shown to be one worthy of discussion, and the question seems to turn on two points:—

1. The real intrinsic value of purely geometrical methods.

2. The practical value of such methods to the ordinary engineer.

1. That projective geometry leads to wide and important generalisation there can be no doubt, but that the benefit is so great as to make it inexpedient to apply the analytic process to arrive at geometric results is quite another question.

Culmann, not altogether unnaturally, criticises those who employ his results, but arrive at the understanding of them by other channels than his own; but can the statement in the preface to the French translation of his work be sustained in which he says—

'Our publication was followed by a great number of elementary statics, in which, by reproducing even the most simple of our constructions, mostly without changing anything in them, the authors have striven to give analytical demonstrations of them.

'We imagine that the truth is not there—that one will never succeed in tracing the lines of a construction, and execute simultaneously algebraical operations which carry the explanation of that construction. Neither can one easily understand the signification of each line, and represent to themselves statical relations, if one limits oneself to translate the formula whose developments are no longer clear to the memory.'

If there is any truth in the preliminary remarks in this report, it is, after all, merely a question of regarding either the actual position of lines or the measurement of that position as representing the same thing to the mind, and it is certain that much that is useful in even Culmann's works has absolutely no necessary connection with projective geometry; while some of his admirers, who quote his views at the beginning of their works on graphical statics with some amount of favour, actually employ largely the analytical methods, and, indeed, scarcely employ the methods of higher geometry at all. Professor Jay Du Bois [1] may be quoted as a good example of this.

But, after all, the practical problems of engineers lie almost entirely in two dimensions of space, and it is perfectly possible to arrive at an understanding of the ordinary problems which arise, by a due harmony of analytical and graphical methods.

2. The second point is one which can only be answered by reference to the actual education of the engineer. Culmann's preface to the German edition of 'Die Graphische Statik,' speaking of the professors of South Germany, says:—

'They were, indeed, totally opposed to the idea of regarding bodies in which forces are in equilibrium and lineal forms which represent these forces in magnitude and direction as correlative geometrical representations, and then applying to these the geometry of position, in which the relations of such allied representation lay completely worked out.

[1] *Graphical Statics*, 2nd ed., by Jay Du Bois. J. Wiley & Sons, New York

One man remarks that 'the interesting and practically useful results which statics afford would already have found common use if the scientific methods of modern geometry had not withheld many engineers from the study of this subject.' The much-respected professor wishes to make it more elementary, but he cannot bring that about without d and $\int$; and yet a knowledge of d and $\int$ requires a greater exercise of brain-power than the elements of the geometry of position does.

The question is, if the d and $\int$ have to be learnt (as they certainly should be) for a great number of other applications, and the engineer finds it more easy to employ a method of reasoning with which he is familiar, will he not certainly do so?

Lastly, there is the argument, so often adduced, of the intellectual value of general methods, and doubtless it is true that a higher mental effort is required to reason from the general to the special, such as is required in the methods of projective geometry. However, teachers are almost unanimous in agreeing that the average student finds it far more easy to reason from the special to the general; nay, it may be truly said that the number of students who have the power of grasping generalisations, such as are expected in the study which has just been discussed, is extremely limited, and that the result of trying to introduce this method is frequently disheartening to the majority of students, who would otherwise acquire sufficient knowledge of the subject for all the practical application they would ever have occasion for.

So much space has been given for the setting forth of these views, and to bringing forward various views on the subject because of its importance, that the writer is unable for want of time to proceed further in time for the presentation to the Association in the present year.

The object in view at the commencement was to collect and summarise all the problems of mechanical science for which graphical calculation and methods were employed. That he is unable to do for the present, and can only offer the following brief outline of the subject, dealing fully with two sections, indicated below, leaving it for the Committee of the Section to say whether they think it desirable that a further report should be presented.

Summary of Graphical Problems.

1. The addition of parallel segments, including sliding calculation and slide rules (which latter are dealt with in the present report).

2. The addition or combination of non-parallel segments.

3. The applications of graphical multiplication, including planimeters and integrators, which are also dealt with.

1. The first of these, as far as regards sliding calculation, has been dealt with at tolerable length, and brought as far as possible up to date.

There are numerous other applications of the addition of parallel forces. The most important of these are the treatment of loads, including the load on a beam, and the weight and buoyancy of a ship.

These problems are dealt with in numerous works; for example, the subject of shearing forces, the construction of diagrams of which for every possible kind of loading might form a subject of somewhat lengthy treatment.

2. The second division, viz., the addition of non-parallel segments, covering, as it does, the whole range of the most fertile branch of graphic statics, is worthy of a separate report. It must suffice here to give the following as amongst the different headings under which it might be treated:—

(*a*) The study of reciprocal figures.
(*b*) Diagrams of forces for framed structure.
(*c*) The polygon of forces, and its application to arches and suspension bridges.
(*d*) The subject of internal stress and the ellipse of stress.
(*e*) Machine problems dealing with the efficiency of machinery, as proposed by Fleeming Jenkin, and the 'method of instantaneous centres,' applied with such effective results by Professor Kennedy in his 'Mechanics and Machinery.'
(*f*) Velocity of machine parts.
(*g*) Hydro-mechanics.
(*h*) Crank effort diagrams, &c.

3. As to the third division almost a wider range opens out, commencing with the principle of what Culmann calls 'the rope polygon,' or 'funicular polygon,' and which he treats in his book under the heading of 'Summation.' By means of this he shows how not only single but whole series of lines of different ratios may be multiplied together, and which, under the title of 'Culmann's Method,' is employed for the purpose of bending moment, moment of inertia, finding the central ellipse and the kern of sections, and still further applied in problems of deflection and continuous girders.

How fertile this graphic method may be made may be seen from the following remark in Cotterill's 'Applied Mechanics,' second edition, p. 303:—

'Thus it appears that the curves of deflection, slope, and bending moment are related to each other in the same way as the curves of bending moment, shearing force, and load.

'The five curves, in fact, form a continuous series, each derived from the next succeeding by a process of graphical integration.'

These are only a few of the problems to which graphical method lends itself, and in connection with which there is abundant scope for investigation and original research.

Addition of Parallel Segments, Sliding Calculation, and Slide Rules.

Shortly after the invention by John Napier, in 1614, of logarithms, Edmund Gunter, Gresham Professor, laid them down on a scale, so that by means of a pair of compasses arithmetical questions might be solved. Mr. Heather, in his work on mathematical instruments,[1] gives a full explanation of the use of 'Gunter's lines,' as they were called, which included not only logarithms of numbers, but other lines graduated so as to represent logarithms of the sines, tangents, &c., and other calculated values useful to navigators.

Gunter's scale and its uses are also described. The sliding Gunter's

[1] *Mathematical Instruments*, by J. F. Heather, M.A., 1880. Crosby, Lockwood, & Co.

scale appears to have been the first sliding rule ever made, and has since been followed by a very large number of others.[1]

Writers on graphic statics recognise the slide rule as an example of the graphical method of calculation. Culmann, in the second edition of his book, gives a treatment of the subject (which he did not do in his first edition), and states in the preface that 'the chapter on sliding calculation was added to that on graphical calculation. It consists really of many treatises on sliding calculation. Addition of logarithms is not considered as a consequent row of lines, but rules are given on independent figures placed opposite each other, by whose means the number of rules is immensely increased. Moreover, this very useful little instrument is much too little used, and I thought to add to its extension by introducing its theory in graphical calculation, to which it properly belonged.'

The use and theory of the slide rule are fully described in the English treatises mentioned in the footnote below,[2] and need not be further dealt with.

It is also treated, in addition to Culmann, by various other foreign writers, in works on graphic statics. Favaro, amongst others, states that Sedlaczek[3] mentions sixteen different kinds of instruments using logarithmic division, as follows:—

1. The ordinary sliding rule.
2. Rule of d'Aesterle.
3. The calculating-rule of Lenoir.
4. The rule of Schwind.
5. Engineer's sliding rule.
6. The rule of L. C. Schulz.
7. The inverted slide rule.
8. The rule of Higgison.
9. The improved calculating-rule.
10. A rule for millwrights.
11. A rule for marine use.
12. Sliding rule for timber measurements.
13. Dr. Roget's sliding rule.
14. A sliding rule for calculating prices.
15. Chemical sliding rule. Wollaston's ('Phil. Trans. R.S.,' 1814).
16. Sedlacrek's slide rule for interpolation.

The following slide rules are mentioned by Mr. Heather:—

1. The Routledge.
2. Bayley's slide rule.
3. The Kentish slide rule.

[1] According to de Morgan (*see* his valuable article on the Slide Rule in the *English Cyclopædia*), the slide rule was invented by Oughtred.

[2] *The Slide Rule, and How to Use It*, by Charles Hoare, C.E. (Weale Series.) Crosby, Lockwood, & Co.

Instructions for the use of Carpenter's Improved Slide Rule, by Edward Preston. Josiah Allen, Birmingham.

Handbook of the Slide Rule, by W. H. Bayley. Bell, London.

Handbook of the Double Slide Rule, by W. H. Bayley. Bell, London.

The Theory and Practice of the Slide Rule, by Lieut.-Col. J. R. Campbell. E. & F. N. Spon, London.

And the following American books:—*The Slide Rule Practically Considered*, by W. H. Burgh; and *The Slide Rule Simplified*, by R. Biddell, Philadelphia.

[3] *Leçons de Statique graphique*, Antonio Favaro. Paris, 1885.

4. Coulson's slide rule.
5. The cubing slide rule.
6. The timber contenting slide rule.

In addition to these, Favaro adds twenty-nine others, of which the following are a few referring to mechanical science :—

1. Hoare's sliding rule, London.
2. Palmer's computing scale, New York.
3. Fuller's computing telegraph, New York.[1]
4. Logarithmic disc of Sonne, Paris.
5. Lalanne's rule, Paris.
6. Scale and rule of Mannheim.
7. Soldati's rule, Turin.
8. Arithmetograph of Quintino Sella, Turin.
9. Cylindrical arithmetograph of Porro, Turin.
10. Everett's proportion table, London.
11. Boucher's calculating circle, Paris.
12. Routledge's slide rule, London.
13. Hawthorn's slide rule, London.
14. Stanley's builders' calculating rule, London.
15. Tavernier Vinay et Tavernier Gravet's calculating rule, Paris.
16. Coggeshall's slide rule, London.
17. Bradford's sliding rule, London.
18. E. Peraux's calculating rule, Nancy.
19. Dennert and Pape's calculating scale, 'Deutsche Bauzeitung,' vol. viii. p. 136.
20. Eschmann's calculating scale, Aarau.
21. Moinot's calculating rule, Paris.
22. Castigliano's arithmetograph, Turin.

This list suffices to show that almost every kind of variation may be made in the form of slide rules; there are a few others, which do not appear to be described in any book in this country, which may be mentioned, viz. :—

1. Boucher's patent calculator, which is only of the size of an ordinary watch. It has faces back and front. On the front is a logarithmical scale in four lines, being on the whole equal to 15 inches of straight scale. This produces a more open scale than the ordinary slide rule. There are two index hands, one on the central axis, and one fixed upon the side of the case. The central hand revolves by the turning of a milled head at the side of the case. The entire dial revolves by the milled head upon one face ; any operations in addition, subtraction, multiplication, division, and proportion can be performed to four places of figures. And upon the other face trigonometrical calculations, viz., logarithms, powers, and roots.

2. Hudson's horse-power computing scale may be mentioned as a convenient little pocket instrument with two sliding scales. By this means

[1] The following notice appeared with this instrument :—'A most wonderful and extraordinary instrument, by which business questions of every possible variety are instantly performed; a safe and speedy check to avoid vexatious errors, and afford at the same time a greater amount of practical business knowledge than can be obtained from ten times the cost of the work.' Sold only by subscription. John E. Fuller, proprietor, New York.

the following quantities can be easily calculated:—(*a*) Horse-power of an engine, (*b*) the necessary size of an engine for any desired power, (*c*) piston speed, (*d*) the mean pressure of a simple or compound engine, (*e*) ratio of compound cylinders.

3. Professor Fuller's spiral calculating rule is specially described by both Culmann and Favaro, and consists of a cylinder that can be moved up and down upon and turned round an axis, which is held by a handle. Upon this cylinder is wound in a spiral a single logarithmic scale. Fixed to the handle is an index. Two other indices, whose distance apart is the axial length of the complete spiral, are fixed to the cylinder. This cylinder slides in like a telescope tube, and thus enables the operator to place these indices in any required position relative to the cylinder. Two scales are provided, one on the piece carrying the movable indices, the other on the cylinder. The inventor remarks that it must be remembered that all calculations founded on measurements of length, weight, and time can only be approximate, as the data for them are so. Except, therefore, with the most refined measurements, it is a waste of time to carry results beyond the fourth figure. The new rule possesses advantages over the old form besides that of increased length of scale. The setting and reading are performed by indices, and not by scale against scale, and this is very much less troublesome. Also, multiplications and divisions containing a series of factors can be worked with the greatest facility, and as the logarithms of numbers by the use of scales are easily read, the powers and roots of numbers are within the capacity of the instrument.

4. Thacher's cylindrical slide rule. The ordinary sliding rule in use is 12 inches long, with radii of 11 and $5\frac{1}{2}$ inches, the divisions of which are cut by hand, copying from a machine-divided plate. In Thacher's instrument the radii are 60 and 30 feet, the divisions of which are printed directly from machine-divided plates. These plates contain over 33,000 divisions, calculated to seven places of decimals from Babbage's tables by using a common multiplier, every line being subjected to correction for error of screw and temperature variation, so that possibly every line-centre is within ·0001 inch of its true place. The plates contain over 17,000 engraved figures. The scales, being of great length, will give results correctly to four, and usually to five, places of figures.

The instrument consists of a cylindrical slide provided with a knob at each end, and which admits of both rotary and longitudinal movement within an open framework or envelope of equidistant bars of triangular section. The bars are connected to rings at their ends, which admit of rotation within standards attached to the base. The surface of the slide is exposed in the openings between the bars, the lower edges of which are in contact with it.

The scales for this instrument have a length forty times as great as for an ordinary slide rule of the same length, and more than sixty-five times as great as for the ordinary slide rule in use.

With this instrument directions are given for not only performing the ordinary arithmetic operations, but for the conversion of foreign weights and measures, calculations and action with money matters, mechanics, specific gravity, timber mensuration, gauging, railway work, weights of metal, calculations for plate girder bridges, truss bridges, &c.

5. Gravet's calculating rule, by which calculations involving squares,

square roots, cubes, cube roots, sines, tangents, and logarithms, are carried out.

The last five instruments can be obtained from Mr. W. F. Stanley, 5 Great Turnstile, London, W.C.

Planimeters and Integrators.

The first recorded idea of the planimeter is attributed to Hermann, of Munich, who worked it out with Lammle. The idea of Hermann's, which was published in 1814, seems to have fallen into oblivion; while in 1827 Oppikofer, of Berne, constructed a planimeter which was called by his name. Professor T. Gonella, of Florence, in 1829 re-invented a similar instrument. Oppikofer's planimeter was accorded a prize at Paris in 1836. Improvements were made by Wettle and Starke in 1849. In England, Sang, Moseley, and others also devised planimeters. All these depended on the principle of recording the area by revolutions of a roller which worked by frictional contact, sometimes on a disc and sometimes on a cone, its distance from the centre of the disc or the apex of the cone being proportional at every distance to the breadth of the figure whose area was to be measured, the revolution of the cone or disc depending at the same time on the length of the figure.

In 1856 Professor Amsler-Laffon invented and brought before the world the well-known Amsler planimeter, which has proved up to the present day to be the simplest and best of all such instruments, in spite of all attempts that have been made to improve upon it and obviate its one or two defects. The action of the Amsler planimeter, as is well known, depends upon the principle that a roller, if moved obliquely across a smooth surface, turns through an amount corresponding to the distance it has moved perpendicular to its axis. Hence the breadth of a figure being measured by the inclination of a bar carrying the roller, and the length by the distance which the wheel moved, the actual turning of the roller gives a record of the area.

The following measurements made by General Peaucellier, cited by Favaro, give the results of the measurements of a quarter of a circle ten millimetres radius divided into ten segments by parallel ordinates, and show the accuracy of the Amsler planimeter as compared with other methods:—

	Areas	Errors
Method of chords	77·611	0·929
Simpson's rule	78·173	0·367
Method of tangents	78·809	0·269
General Poncelet's rule	78·403	0·137
General Peaucellier's rule	78·763	0·223
Measurements by planimeter	78·655	0·115
Exact area	78·540	

Explanations of the action of a planimeter are given in many text-books on mechanics; a very good account on elementary principles is that of Sir F. J. Bramwell.[1]

By means of a very simple device of two points attached to the Amsler planimeter, the scale of the reading can be adjusted to suit any

[1] 'On the Amsler Planimeter,' by F. J. Bramwell. *Report of the British Association*, 1872, p. 401

diagram. The two defects in this class of instrument are: first, the comparatively small scale of the recorded results; and, secondly, the slight variation which occurs owing to different kinds of paper being used for diagrams on which the planimeter has to operate. A class of instruments has therefore been invented called precision polar planimeters, the first attempt in this direction being by Mr. Hohmann, of Bamberg, in 1882, in conjunction with Coradi, of Zurich. In this planimeter what corresponds to the rolling wheel of the Amsler planimeter works on a prepared disc, which in turn is driven by rollers from the paper, so that the result is very much magnified. At the same time the roller itself always works upon the same surface. A number of such instruments have since been devised, many of which were exhibited among the scientific instruments at the International Inventions Exhibition at London, 1885, and the more important have been described in a paper on integrators by the writer.[1]

In all these planimeters the roller slips over the surface, but there is another totally different class of instrument in which no slipping of the roller as it moves to and fro is supposed to take place. Such a planimeter was suggested by the late Professor Clerk Maxwell.[2] On such a principle also the disc, globe, and cylinder integrator of Professor James Thomson has been designed. This mechanism has been used by Sir William Thomson in his tide-calculating machine already referred to, and obtains the harmonic analysis of the tides for subsequent operations with the tide-predicter.

Instruments of this class have been designed by Professor Vernon Boys, Mr. Abdank Abakanowicz, and the writer. These instruments are referred to in the paper by the writer already mentioned, and also in a recent treatise on 'Intégraphes.'[3] This treatise commences with an explanation of the properties of the integral curve, and then proceeds to describe integrators in which the area of a figure is measured by the height to which a roller rises in the curve of its movement round the periphery of the curve to be integrated. A number of integrators, or instruments for drawing an integral curve, designed by Mr. Boys, M. Zmurko, and Mr. Abdank Abakanowicz, are then described. The work, which contains 150 pages, then proceeds to describe the application of these instruments to various mechanical problems, such as bridges, earthworks, naval architecture, electric machines, and for obtaining the work performed by engines.

A new planimeter is made by Messrs. Richard Frères in which there is no contact between the paper and the totalising mechanism, but which employs the old principle of the disc and roller. The following explanation is supplied by Mr. Berly, Messrs. Richard Frères' manager:—

'The surface is the function $\int_o^x e dx$, e being the ordinate, x the abscissa. The planimeter executes exactly this sum of differentials; it is composed

[1] 'Mechanical Integrators,' by Professor Hele-Shaw. *Min. Proc. Inst. C.E.*, vol. lxxxii.

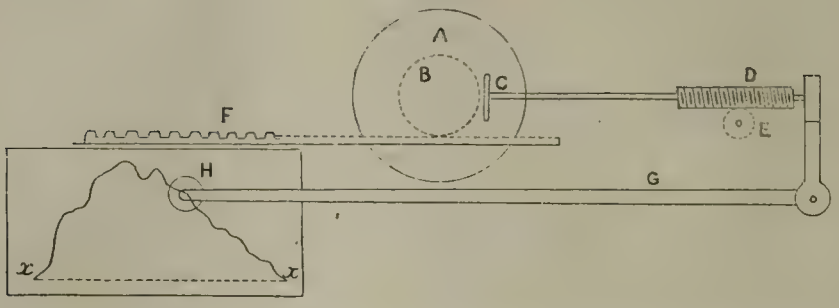
[2] 'Description of a New Form of Planimeter, an Instrument for Measuring the Areas of Plain Figures Drawn on Paper,' by James Clerk Maxwell. *Trans. Royal Scottish Soc. of Arts*, 1855.

[3] *Les Intégraphes. La Courbe intégrale et ses Applications*, par Abdank Abakanowicz. Gauthier-Villars, Paris, 1886.

in principle of a plate, A. On this moves, in the direction of the radius, a roller, C. It is quite evident, if we make the plate A turn, the number of turns made by the roller will be proportional to the number of turns made by the plate A.

'If we suppose the curve to be planimetrical, mounted on a rack, F, working with a pinion, B, fixed on the same axis as the plate, while

FIG. 36.



from the other side we guide the roller by means of a lever, G, so that the extremity, H, of this lever is on the axis of x when the roller is at the centre of the plate, then we shall displace the curve while following the turning of the disc and roller.

'The plate A will turn as a function of the abscissæ $x\,x$. The distance from the centre of the plate to the roller will be at each moment proportional to the different ordinates of the curve; consequently, if we make a wheel move endlessly with the screw D on the axis of the roller, the product will be the sum of all the differentials,

$$\int_o^x e dx.$$

'In practice the rack is replaced by a toothed wheel or a crank, and the plate is composed of a system of two wheels turning in a contrary way, compressing between them the roller.

'At the same time, for greater convenience, the curve is fixed on a cylinder similar to all those we make. The advantage over all other planimeters is that, should the roller produce an error in making a great number of turns, it is absolutely due to negligence, and the apparatus gives the reading directly in square millimetres, the approximation being at least one-millionth of the total value.'

In order to use the instrument the paper is fixed upon the drum, a knob is held in the right hand and pressed against the flange at the bottom part of the cylinder; then the crank is turned until one of the ordinates, passing through any point on the diagram, comes under the point with the knob. The starting-point of the diagram is then marked by means of a pencil point, and after bringing the point to this mark, the crank is turned until a starting-point is again reached. A guiding pointer is then brought against the flange, and the reading of the index gives the area of the diagram. The writer has not been able to obtain one of these instruments so as to actually test them, and makes the above statement solely on the high authority of the makers; but it is

to be noted that the theory of the instrument is the same as that of the Wettle-Starke, being simply a disc and roller integrator.

Closely allied to instruments for obtaining the area of the surface are the moment planimeters. There are two possible ways of employing planimeters for this purpose. The first of these ways was suggested in connection with the disc, globe, and cylinder integrator by Sir William Thomson,[1] and amounts to the integration of a simple linear differential equation. This method has been treated in a paper[2] in connection with sphere and roller mechanism. Another principle is to cause the measuring roller to be directly turned at a rate which is made to vary, not, as in the simple planimeter, with the value of the ordinate (y), but with its second or third power. Though no method of directly doing this has apparently been suggested, yet the same result is practically effected by the beautiful application of a mathematical principle in the 'moment integrator' of Professor Amsler.

This instrument can be employed for obtaining the contents of embankments and the material moved in cuttings for civil engineering purposes, in which not only the cross-sections vary, but the slope and surface of the ground. These and other matters are described at length, and also the limits of accuracy of planimeters are given, in a paper already alluded to on mechanical integrators, in the 'Proceedings of the Institution of Civil Engineers,' vol. lxxxiii. For the history of planimeters the following paper by Favaro may also be cited: 'Beiträge zur Geschichte der Planimeter,' von Dr. Antonio Favaro, 1873, published by V. Waldheim, Vienna.

The writer wishes to express his acknowledgment of the valuable aid rendered him by his assistant lecturers, Mr. R. Holt (Whit. Schol.), in preparing many of the diagrams, and Mr. J. F. Conradi, in connection with the references in the Appendix.

APPENDIX.

CLASSIFIED LIST OF REFERENCE TO GRAPHICAL METHODS.

The following is a list of Transactions, Proceedings, and Periodicals which have been examined:—

Transactions and Proceedings.

Report of the British Association for the Advancement of Science.
Transactions of the Chesterfield and Midland Institution of Engineers.
Transactions of the Institution of Engineers and Shipbuilders in Scotland.
Proceedings of the Institution of Civil Engineers.
Proceedings of the Institution of Mechanical Engineers.
Journal of the Iron and Steel Institute.

[1] *Proceedings of the Royal Society*, vol. xxiv. p. 262, and vol. xxvii. p. 371.
[2] 'Theory of Continuous Calculating Machines,' by Professor Hele-Shaw. *Philosophical Transactions of the Royal Society*, Part II. 1885.

Proceedings of the Literary and Philosophical Institution of Manchester.
Transactions of the Institution of Naval Architects.
Transactions of the Midland Institute of Mining, Civil, and Mechanical Engineers.
Proceedings of the Manchester Steam Users' Association.
Transactions of the Mining Institute of Scotland.
Transactions of the North-east Coast Institute of Engineers and Shipbuilders.
Transactions of the North of England Institute of Mining and Mechanical Engineers.
Proceedings of the Royal Society, London.
Proceedings of the Royal Society, Edinburgh.
Proceedings of the Royal Irish Academy, Dublin.
Proceedings of the Royal Engineers.
Proceedings of the Royal Artillery Institution.
Transactions of the Society of Engineers.

Periodicals.

The Engineer.
Engineering.
The Electrical Engineer.
Industries.
Iron.
The Marine Engineer.
The Practical Engineer.
The Railway Engineer.
The Sanitary Record.

The following are headings, arranged in alphabetical order, under which references are classified in order of the year of publication :—

Air Properties 435
Artillery and Explosives . . 436
Brake Trials 438
Canals 439
Discharge of Water . . . 439
Drainage and Sewage . . 441
Drawing Instruments and Recording Instruments . . 441
Earthwork Quantities . . 446
Electricity and Magnetism . 446
Engine Tests and Diagrams:
Air Engines . . . 454
Gas Engines . . . 456
Hydraulic Engines . . 458
Land Engines . . . 458
Locomotive Engines . . 459
Marine Engines . . . 462
Oil Engines . . . 469
Refrigerating Machines . 470
Stationary Engines . . 470
Flow of Gases 483
Friction 483
Heat 484
Indicators 485
Materials, Properties of . . 485
Mechanism 488
Meteorological 489
Naval Architecture . . . 493
Pumping Engines . . . 502
Railways 507
Screw Propellers . . . 508
Steam, Properties of . . 509
Strength and Stability of—
Arches 510
Boilers 511
Bridges and Girders . . 514
Chimneys and Towers . 519
Dams and Dock Gates . 519
Lighthouses . . . 520
Piles 520
Retaining Walls . . 520
Riveted Joints . . . 521
Roofs 521
Struts 522
Strength of Materials . . 522
Tides 526
Valves and Valve Gears . . 526
Vibrations 530
General 530

Subject	Author	Journal	Vol. and Page	Date	Kind of Curve
		AIR PROPERTIES.			
Observations on Diverging Streams of Compressed Air	T. Hopkins	Proc. Lit. and Phil. Soc. Manchester	V. 2nd series	1831	—
Velocity of Currents of Air in Mines	J. J. Atkinson, J. Daglish	Proc. N. Eng. Inst. Mining Engineers	X. 207	1861	Comparison of anemometers.
Discussion on the Use of Compressed Air	Prof. Herschel	Proc. N. Eng. Inst. Mining Engineers	XXII.	1872–3	Indicator diagrams.
Properties of Air	Prof. R. H. Thurston	Engineering	XVIII. 16	1874	Curves of pressure and temperature.
Mechanical Properties of Gases	W. West	Engineer	XXXIX. 289 to XL. 55	1875	Diagrams.
Air Compression	J. Steel	Engineer	XLI. 473	1876	Pressure curves.
Compressed Air	T. W. Lightfoot	Engineer	LI. 104	1881	Indicator diagrams.
Birmingham Compressed Air Supply	Anonymous	Engineer	LIX. 121	1885	Expansion curves.
Explosion of Homogeneous Gaseous Mixtures	D. Clerk	Proc. Inst. C.E.	LXXXV. 7	1885–6	Explosion of gases.
Continuity of Liquid and Gaseous State	W. Ramsay, S. Young	Proc. Roy. Soc. Lond.	XLII. 3	1887	—
Change of State from Liquid to Gas	G. F. Fitzgerald	Proc. Roy. Soc. Lond.	XLII. 217	1887	—
Explosions of Air and Coal Gas	G. C. Douglas	Engineer	LXIII. 308	1887	Pressure and time curves.
Flow of Gases	O. Reynolds	Proc. Lit. and Phil. Soc. Manchester	X. 3rd series	1887	—
Air Vessels	D. Baird	Trans. of Mining Inst. of Scot.	X.	1888–9	Indicator diagrams.
Air in Coal Mines	Dr. Nasmyth	Trans. of Mining Inst. of Scot.	X.	1888–9	Diagrams of temperature.
Atmospheric Resistance	O. T. Crosby	Engineering	XLIX. 716	1890	Curves of velocity and pressure.
The Paris Compressed Air System	Anonymous	Engineering	LI. 297	1891	Compound diagrams.
The Paris Compressed Air System	Anonymous	Engineering	LI. 513	1891	Compound diagrams.
Compound Air Compressors and Motors	Prof. A. C. Elliott	Engineering	LII. 674, 703	1891	Indicator diagrams; diagrams of efficiency.

Subject	Author	Journal	Vol. and Page	Date	Kind of Curve
		ARTILLERY AND EXPLOSIVES.			
Lectures on the Science of Gunnery	Capt. Boxer	Mins. of Proc. of Roy. Art. Inst.	I. 275	1854	Diagrams of the force of gunpowder.
Construction of Artillery	J. A. Longridge	Proc. Inst. C.E.	XIX. 283	1859–60	Tension and compression curves.
On some Geometrical Constructions connected with Elliptic Motion of Projectiles	Prof. P. G. Tait	Proc. Roy. Soc. Edinb.	V.	1865	—
Barytic Gunpowder	C. Vignoles	Engineering	II. 150	1866	Curves of velocity (Brit. Assoc. paper).
Mr. Whitworth's Experiment on Projectiles	Anonymous	Engineering	III. 469	1867	Diagram to determine the effect of different pitches of rifles.
Martini-Henry Rifle	Anonymous	Engineering	VII. 233	1869	Diagram of the effect of recoil.
Apparatus for Measuring the Velocity of a Shot	Capt. W. H. Noble	Engineering	VIII. 335	1869	Recording instrument; curves of time, velocity, and pressure (Inst. Mech. Engs., 1869).
The Abouchoff Cast Steel Works	Anonymous	Engineer	XXX. 107	1870	Relative efficiency of guns.
Strength of Gunpowder	Anonymous	Engineer	XXX. 183	1870	Pressure curves.
Le Chatelier's Plan of using Counter-pressure as a Brake on Locomotive Engines	C. W. Siemens	Proc. Inst. Mech. Engs.	— 21	1871	Reverse working counter-pressure diagrams.
Heavy Breach-loading Gun	Capt. J. P. Morgan	Mins. of Proc. Roy. Art. Inst.	VII. 145	1871	Circumferential strain.
Mallet's 36″ Mortar	Major G. Lefroy	Mins. of Proc. Roy. Art. Inst.	VII. 203	1871	Diagram of practice.
Explosive Force of Gunpowder	Capt. J. P. Morgan	Mins. of Proc. Roy. Art. Inst.	VII. 413	1871	Pressure curves.
Materials for Artillery	Anonymous	Engineer	XXXIII. 179	1872	Strain diagrams.
Graphical Solution of Problems in Artillery	Major W. H. Wardell	Mins. of Proc. Roy. Art. Inst.	VIII. 316	1874	Artillery.
On the Pressure required to give rotation to Rifled Projectiles	Capt. A. Noble	Mins. of Proc. Roy. Art. Inst.	VIII. 359	1874	Pressure on studs.
Heavy Guns	Anonymous	Engineering	XIX. 95	1875	Diagram showing the power of projectiles.
Hydraulic Gun Carriages	Lieut. Razkazoff	Engineering	XXIII. 305	1877	Diagram of pressure in the plunger.
Explosion on board the 'Thunderer'	Anonymous	Engineer	XLVII. 244	1879	Diagram illustrating report.

Gun Carriages of the Circular Ship, Vice-Admiral 'Popoff'	Anonymous . .	Engineer . . .	XLVII. 339	1879	Diagram of the stroke of plungers.
Hydraulic Compressors for Gun Carriages	Anonymous . .	Engineering . . .	XXVIII.122, 461	1879	Curves of resistances.
Hydraulic Compressor for Gun Carriages	Anonymous . .	Engineer . . .	LI. 443	1881	Pressure and recoil.
Forces and Strains of Recoil considered with reference to the Elastic Field Gun Carriage	H. J. Butter .	Proc. Inst. C.E. . .	LXVII.	1881–2	Time curves of recoil.
British Naval Gunnery . . .	Anonymous . .	Engineering . . .	I. 37	1884	Diagram of internal stresses.
British Naval Gunnery . . .	Anonymous . .	Engineering . . .	I. 135	1884	Curve of strain.
Rifles for Large Game . . .	Major W. McClintock	Mins. of Proc. Roy. Art. Inst.	XII. 569	1884	Trajectories of spherical and conical bullets.
The Precision of Firearms . .	Capt. MacMahon .	Mins. of Proc. Roy. Art. Inst.	XII.	1884	Diagrams of curves on the precision of firearms.
The Calculations of Trajectories in direct and curved fire	A. G. Greenhill .	Mins. of Proc. Roy. Art. Inst.	XIII. 53	1885	Diagram connecting velocity and pressure.
Guns as Heat Engines . . .	W. Anderson .	Engineer . . .	LIX. 112	1885	Curves of pressure and work.
Method of compiling a Range Table	Commander H. J. May	Mins. of Proc. Roy. Art. Inst.	XIV. 353	1885–8	Range curve.
The Collingwood Gun . . .	J. A. Longridge .	Engineering . . .	XLII. 367	1886	Diagram of work done.
The Protection of Heavy Guns for Coast Defence	Capt. Clarke .	Mins. of Proc. Roy. Art. Inst.	XV. 155	1886–7	Diagrams of angles of impact.
Elswick's Newcastle Exhibits .	Anonymous . .	Engineer . . .	LXIII. 367	1887	Velocity and pressure.
Submarine Mining	Lieut.-Col. Bucknill	Engineering . . .	XLIV. 189	1887	—
Submarine Mining	Lieut.-Col. Bucknill	Engineering . . .	XLIV. 401	1887	Buoyancy of buoys.
Application of Hydraulic Power to Naval Gunnery	Lord Armstrong, J. Vavasseur	Trans. Inst. Nav. Arch. .	XXIX. 8	1888	Pressure curve drawn by indicator.
Gunnery Questions. . . .	Anonymous . .	Engineer . . .	LXVI. 255	1888	Resistance of air.
Explosions under Water . .	Anonymous . .	Engineering . . .	XLVII. 289	1889	Diagrams of charge.
Gunnery Questions. . . .	Anonymous . .	Engineer . . .	LXIX. 211	1890	Probability factors.
Modern French Artillery . .	Anonymous . .	Engineering . . .	L. 386	1890	Curves of total pressure in cylinders, and velocity of recoil.
		BRAKE TRIALS.			
Dynamometer and Friction Brake.	W. Froude . .	Proc. Inst. Mech. Engs. .	— 92	1858	—
The Action of Brakes . . .	Anonymous . .	Engineering . . .	XX. 12	1875	Curve of the effect of retarding power.
Continuous Brakes, North British Railway	Anonymous . .	Engineer . .	XLII. 417	1876	Speed and distance.

Subject	Author	Journal	Vol. and Page	Date	Kind of Curve
		BRAKE TRIALS—*continued.*			
Efficiency of Brakes	E. Woods (Presidential Address)	Rep. Brit. Assoc.	XLVII. 186	1877	Efficiency.
North British Railway	Anonymous	Engineering	XXIII. 12	1877	Curves of Westinghouse and Smith Brakes.
North British Railway	Anonymous	Engineering	XXIII. 469	1877	Curves of Westinghouse and Smith Brakes.
North British Railway	Anonymous	Engineering	XXIV. 263	1877	Distance and force diagrams.
North British Railway	Anonymous	Engineer	XLIII. 2	1877	Speed and distance.
Brake Trials in Germany	Anonymous	Engineer	XLIV. 217	1877	Curves of momentum.
The Hatfield Accident	Anonymous	Engineering	XXV. 30	1878	Diagrams of speed.
Action of Brakes	Capt. D. Galton	Engineering	XXV. 471	1878	Diagrams of friction (Inst. Mech. Engs. 1878).
Continuous Brakes	Anonymous	Engineering	XXVI. 400	1878	Friction diagram; diagram of velocity.
On the Effect of Brakes upon Railway Trains	Capt. D. Galton	Engineering	XXVI. 386, 396	1878	Diagrams of velocity and time for stopping.
Action of Railway Brakes	Anonymous	Engineer	XLV. 455	1878	Time and pressure.
Report on Continuous Brakes	M. G. Marie	Engineer	XLVI. 76	1878	Pressure and distance (Inst. Mech. Engs. 1878).
Report on Continuous Brakes on the North-eastern Railway	Capt. D. Galton	Engineer	XLVI. 308	1878	Pressure and time.
The Westinghouse Brake	Anonymous	Engineering	XXVII. 85	1879	Diagram of velocity, and time of stopping curves of friction.
The Effect of Brakes on Railway Trains	Capt. D. Galton	Engineering	XXVII. 373	1879	As effected by speed and time (Inst. Mech. Engs.).
Continuous Brakes	M. G. Marie	Engineering	XXVII. 383	1879	—
Westinghouse Brake	Anonymous	Engineering	XXVIII. 74	1879	—
Smith's Vacuum Brake	Anonymous	Engineer	XLVII. 21	1879	Pressure of steam and vacuum.
Brake Resistance	Anonymous	Engineer	XLVII. 78	1879	Pressure and speed.
Lyons Railway Brake Experiments	M. G. Marie	Engineer	XLVII. 308	1879	Pressure and speed.
Brake Trials, North-eastern Railway	Anonymous	Engineer	XLVIII. 51	1879	Pressure and speed.
Westinghouse Brake	Anonymous	Engineer	XLVIII. 65	1879	Pressure and speed.
Brakes on the L. & N.W. Railway	Anonymous	Railway Engineer	I.	1880	—

Efficiency of Brakes	Anonymous	Engineer	LII. 196	1881	Diagram giving efficiency.
Vacuum Brake Experiments	Anonymous	Engineering	XXXV. 13	1883	Force and time.
Observations in the Working of Continuous Brakes	G. Richard	Railway Engineer	—	1884	—
Continuous Brakes	H. Graham Harris	Prof. Papers of Corps of Roy. Engs.	XIV.	1888	Diagrams.
Appold Brake	Professor Barr and D. Halpin	Engineer	LXV. 23	1888	Moscrop recorder and trials. Indicator diagrams.
Brake Trials at Carlsruhe	Anonymous	Engineering	XLVII. 622	1889	Speed and resistance.
Westinghouse Quick-acting Brake	Anonymous	Engineering	L. 461	1890	Curve of trial.
CANALS.					
Ganges Canal	Anonymous	Engineering	I. 229	1866	Falls in the canal bed, graphically.
Sewage in France	Anonymous	Engineer	XXVI. 341	1868	Diagrams of sewer water, &c.
The River Witham Drainage	Anonymous	Engineering	VIII. 233	1869	Curve showing the quantity of water lifted for every number of revolutions.
Manchester Ship Canal	Anonymous	Engineering	XXXVIII. 192	1884	Diagrams showing simultaneous levels of high spring tide.
Panama Canal	Anonymous	Engineer	XXVIII. 47	1889	Progress diagrams.
DISCHARGE OF WATER.					
Discharge of Elastic Fluids under Pressure	W. Froude	Proc. Inst. C.E.	VI. 356	1847	Curves of flow.
Discharge of Water	T. E. Blackwell	Proc. Inst. C.E.	X. 330	1850–1	Curve of discharge.
Water Supply	B. Latham	Trans. Soc. Engs.	p. 252	1864	Impurities per gallon.
Flow of Water off the Ground	R. Manning	Proc. Inst. C.E.	XXV. 458	1865–6	Diagram of water storage and supply.
Apparatus for Measuring the Discharge of Water	Anonymous	Engineering	IV. 124	1867	Construction of curve.
Apparatus for Measuring the Discharge of Water	Anonymous	Engineering	IV. 145	1867	Construction of curve.
Flood Discharge of Rivers	P. P. L. O'Connell	Proc. Inst. C.E.	XXVII. 204	1867–8	Diagram of flood discharge.
Principle of Stream Lines	Prof. W. J. M. Rankine	Engineer	XXVI. 284	1868	Stream lines.
Fire Engine Nozzles	Capt. E. Shaw	Engineering	VII. 247	1869	Construction of nozzle.

Subject	Author	Journal	Vol. and Page	Date	Kind of Curve
		DISCHARGE OF WATER—*continued.*			
On the Flow of Elastic Fluids through Orifices in Pipes	E. W. Blake.	Engineering	VIII. 418	1869	Diagram of densities.
Fluid Friction	W. Froude	Engineer	XXVIII. 186	1869	Resistance curve.
Flow of Liquids through Small Orifices	Col. H. Clerk	Engineer	XXVIII. 257	1869	Velocity.
Constant and Intermittent Water Supply	G. F. Deacon	Proc. Inst. C.E.	XLII. 129	1874–5	Diagram of supply.
Action of Water when Flowing at Different Velocities through a Nozzle	J. Brownlee.	Trans. Inst. Shipbuilders Scot.	XIX.	1875–6	—
Flow of Water through Nozzles	J. Brownlee.	Engineering	XXI. 191	1876	Curves of flow.
Flow of Water through Orifices	J. Thomson.	Rep. Brit. Assoc.	XLVI. 243	1876	Theoretical velocities.
Flow of Water through Orifices and Thin Plates	R. D. Napier	Engineering	XXVI. 145	1878	Curves of pressure.
On the Flow of Water through Orifices	R. D. Napier	Trans. Inst. Shipbuilders Scot.	XXII.	1878–9	—
Graphic Mode of ascertaining flow of a Mill Stream	W. Shelford.	Proc. Inst. C.E.	LVIII. 337	1878–9	—
Flow of Water through Orifices and Thin Plates	R. D. Napier	Engineering	XXVII. 35	1879	Curves of pressure.
Expanding Water-pressure Engine	Anonymous.	Engineering	XXX. 211	1880	Diagram.
Prevention of Waste of Water	T. Stewart	Proc. Inst. C.E.	LXVI. 335	1880–1	Consumption of water.
Fleischer's Hydromotor	Anonymous.	Engineering	XXXII. 261	1881	Indicator diagrams.
Current-meter Observations in the Thames	Prof. W. C. Unwin	Proc. Inst. C.E.	LXXI. 338	1882–3	Ebb and flow tide velocity curves.
The Edinburgh Waterworks	A. Leslie	Proc. Inst. C.E.	LXXIV. 91	1882–3	Consumption of water.
Motion of Water	Prof. O. Reynolds	Proc. Roy. Soc. Lond.	XXXV. 84	1883	Resistance in pipes.
Movement of Water in Tidal Rivers	Prof. W. C. Unwin.	Engineer	LV. 66	1883	Curves of volumes.
Sluice opening of a Tidal Canal	J. H. Apjohn	Proc. Inst. C.E.	LXXVIII. 313	1883–4	Curves of tide levels.
Testing Current-meters	R. Gordon	Engineering	XXXVII. 467	1884	Curves of speed, and travel of meter.
Hydraulic Propulsion	Anonymous.	Engineering	XL. 585	1885	Curves of efficiency of pump, &c.
Measurement of Water over Weirs	B. Donkin, jun., F. Salter	Proc. Inst. C.E.	LXXXIII. 377	1885–6	Diagram of quantity.

Roorkee Hydraulic Experiments	E. S. Bellasis	Trans. Soc. Engs.	[illegible]	[illegible]	[illegible]
Flow of Water in Pipes	Prof. W. C. Unwin	Industries	I. 380	1886	Head lost in pipes.
Molteno Reservoir	C. J. Wood	Proc. Inst. C.E.	LXXXIX.285	1886–7	Fluctuations in rainfall.
Flow of Water in Pipes and other Channels	E. C. Thrupp	Trans. Soc. Engs.	— 224	1887	—
Irrigation in Lower Egypt	Anonymous	Engineering	XLIV. 283	1887	Gauge of water curve.
River Gauging at the Vyrnwy Reservoir	J. H. Parkin	Proc. Inst. C.E.	XCII. 353	1887–8	Velocity curves.
Propulsion by Difference of Fluid Pressure	R. E. Froude	Trans. Inst. Nav. Arch.	XXX. 390	1889	Pressure diagram.
The Liverpool Waterworks	Anonymous	Engineering	XLVII. 153	1889	Diagram of forces on dam.
Flow of Water in Earth Channels	R. Sadler	Proc. Inst. C.E.	CIII. 273	1890–1	Hydraulic mean depth and depth of water.
Water Supply. Birmingham Water Supply	Anonymous	Engineer	LXXI. 295	1891	Consumption of water.
DRAINAGE AND SEWAGE.					
Treatment of Town Sewage	A. Jacob	Proc. Inst. C.E.	XXXII. 371	1870–1	Organic nitrogen in sewage.
Dry Sewage Process	G. R. Redgrave	Proc. Inst. C.E.	XLV. 130	1875–6	Amount of sewage raised.
Sewage Pumping Station, Burton-on-Trent	J. Mansergh	Trans. of Chesterfield and Midland Counties Inst. Engs.	XV. 215	1886–7	Indicator diagram.
Shone Hydro-pneumatic Sewage System	E. Ault	Trans. Soc. Engs.	p. 68	1887	Horse-power and useful effect.
An Examination of Experiments on Sewage	R. W. P. Bird	Sanitary Record	IX.	1887–8	Quantities of iron, &c.
Discharges of Circular and Egg-form Sewers	W. T. Olive	Proc. Inst. C.E.	XCIII. 383	1887–8	Diameter diagram.
Sewage Flow of Chiswick	J. Hetherington	Proc. Inst. C.E.	XCIV. 247	1887–8	Daily fall of sewage, leakage, rainfall.
Lough Erne Drainage	J. Price	Proc. Inst. C.E.	CI. 73	1889–90	Discharge.
Sewer Ventilation	W. S. Crimp	Trans. Soc. Engs.	— 139	1890	—
DRAWING INSTRUMENTS AND RECORDING INSTRUMENTS.					
Prof. Whewell's Anemometer	W. Snow Harris	Report Brit. Assoc.	X. 157	1840	—
Recorder for Registering Distances and Bearing at Sea	Anonymous	Marine Engineer	I.	1856	—
Notes on the Hodograph	Prof. P. G. Tait	Proc. Roy. Soc. Edinb.	VI.	1862–3	—
Stereometric Tablet for the Computation of Earthwork	J. Warner	Trans. Inst. Shipbuilders Scot.	VI.	1862–3	Instrument.

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Improved Steam-engine Indicator	J. Hannan	Trans. Inst. Shipbuilders Scot.	IX.	1865–6	—
Anemometer at the Royal Observatory, Greenwich	Anonymous	Engineering	II. 309	1866	—
Instrument for Ascertaining Speed of Ship	J. R. Napier	Trans. Inst. Shipbuilders Scot.	X.	1866–7	—
Cyclograph	Anonymous	Engineering	IV. 465	1867	An instrument for setting out railway curves.
Water Gauge for ascertaining Pressure of Ventilating Column in Mines	J. Daglish	Trans. N. Eng. Inst. Mining Engineers	XVII.	1867–8	Diagram.
Anemometers	S. B. Howlett	Engineering	V. 511	1868	Recording instrument.
Apparatus for Measuring Steam used by Engines	B. Donkin, B. W. Farey	Engineering	VI. 58	1868	—
Apparatus for obtaining the Resistance of Railway Trains	L. Vuillemin, A. Guebhard	Engineering	VI. 303	1868	—
Wave and Roll Tracer	Admiral E. Paris	Trans. Inst. Nav. Arch.	VIII. 279	1868	—
Sir W. Thomson, Siphon Recorder	Anonymous	Engineering	X. 7	1870	—
Norton and Bailey's Pressure Recorders	Anonymous	Engineer	XXIX. 259	1870	—
Diagrammagraphe	M. Pichault	Engineering	XII. 385	1871	Diagram of steam distributed.
Diagrammagraphe	M. Pichault	Engineering	XII. 428	1871	Diagram of steam distributed.
Statical and Dynamical Pressure	E. Bainbridge	Proc. N. Eng. Inst. Mining Engs.	XXI.	1871–2	Diagram of pressure.
The Scroll Drum	G. Fowler	Proc. N. Eng. Inst. Mining Engs.	XXI.	1871–2	Counterbalancing diagrams.
The Scroll Drum	G. Fowler	Engineering	XIII. 182	1872	Diagrams.
Diagrammagraphe	M. Pichault	Engineering	XIII. 354	1872	Apparatus for drawing valve-gear diagram.
Amsler's Planimeter	Anonymous	Engineering	XIV. 350	1872	—
Automatic Recorder of Rolling of Ships	W. Froude	Trans. Inst. Nav. Arch.	XIV. 168	1873	—
The Cycloscope	Lieut. G. S. Clarke	Trans. Roy. Eng. Inst.	I. 234	1877	Measuring speed of revolving bodies.
Waste Water Meter	Anonymous	Engineer	XXXVII. 59	1874	Diagram of gallons per hour.

Sectograph	Lieut. J. Tressider	Mins. of Proc. Roy. Art. Inst.	VIII. 404	1874	—
Sir W. Thomson's Self-recording Tide Gauge	Anonymous	Engineering	XX. 199	1875	(British Assoc.)
Sir W. Thomson's Self-recording Tide Gauge	Anonymous	Engineer	XXXIX. 125	1875	—
Revolution Indicators	R. H. Crickmer	Engineering	XX. 259	1875	—
A Current Meter	B. T. Moore	Proc. Inst. C.E.	XLV. 220	1875–6	Curves of flow.
Mechanism for Integrating the General Linear Differential Equation of Second Order	Prof. P. G. Tait	Proc. Roy. Soc. Edinb.	IX.	1875–8	—
Improved Apparatus for Drawing Slide Valve Diagrams	Anonymous	Engineering	XXI. 388	1876	—
Wilkinson's Scale for Drawing Steam Curves	Anonymous	Engineering	XXII. 40	1876	—
The Westinghouse Train-speed Indicator	Anonymous	Engineering	XXII. 204	1876	—
Theiler's Patent Speed Recorder and Indicator	Anonymous	Engineering	XXIV. 155	1877	—
Thompson's Indicator	Anonymous	Engineering	XXIV. 312	1877	—
Bailey's Testing Apparatus	Anonymous	Engineer	XLV. 30	1878	Blast recorder and reservoir diagram.
Experimental Brake	Anonymous	Engineer	XLV. 380	1878	Speed recorder.
Observations on Winding Engines	A. Lupton	Trans. Chesterfield and Midland Inst. Engs.	VI. 327	1879	Richard's indicator and velocimeter.
On Parallel Motions	Rev. J. Wilson	Proc. Roy. Soc. Edinb.	XX. 199	1879	—
Theorell Printing Meteorograph	Anonymous	Engineering	XXVII. 6	1879	—
New Steam Engine Indicator	J. E. Sweet	Engineering	XXVIII. 117	1879	—
Edson's Patent Recording Pressure Gauges	Anonymous	Engineer	XLVII. 378	1879	—
Physical Changes in Iron and Steel at High Temperature	—	Journ. Iron and Steel Inst.	I.	1879–80 1891	—
J. Amsler-Laffon's Mechanical Integrator	C. W. Merrifield	Trans. Inst. Nav. Arch.	XXI. 252	1880	—
Mechanical Integrator	C. W. Merrifield	Engineering	XXIX. 462	1880	Instrument to find statical moment of inertia, &c.
Winstanley's Recording Radiograph	Anonymous	Engineering	XXX. 316	1880	—
Darke's High-speed Indicator	Anonymous	Engineer	XLIX. 172	1880	—
Kraft's Indicator	Anonymous	Engineer	L. 415	1880	—
The Amsler-Laffon Integrator	P. S. Hay	Engineering	XXXI. 36	1881	—

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Angas's Parallel Motion	W. M. Angas	Engineering	XXXII. 237	1881	Curve of pressure on motion bar.
Indicators	Anonymous	Engineer	LI. 61	1881	Kenyon's, Darke's, Casartelli's, and Potter's indicators.
Winstanley's Radiograph	Anonymous	Engineer	LI. 138	1881	—
Sir W. Thomson's Siphon Recorder	Anonymous	Engineering	XXXIII. 34	1882	—
Water Meters	J. J. Tylor	Engineering	XXXIII. 108	1882	—
Integrator Water Meters	J. J. Tylor	Engineer	LIII. 87	1882	(Read at Inst. Mech. Eng.)
Experiments to Test the Accuracy of Registering Anemometers	H. S. Snell	Engineer	LIII. 447	1882	—
Pickwell's Self-registering Compass	Anonymous	Engineer	LIV. 273	1882	—
Lea's Planimeter Indicator	Anonymous	Engineer	LIV. 443	1882	—
Current Meter	Prof. Hele Shaw	Engineer	LVI. 329	1883	—
Bate's Hydrometer	Anonymous	Engineering	XXXV. 434	1883	Correction of temperature.
Klose's Speed Recorder for Locomotives	Anonymous	Engineering	XXXVII. 99	1884	—
Rysselberghe's Telemeteorograph	Anonymous	Engineering	XXXVII. 401	1884	Instrument for measuring pressures and temperatures.
The 'Moscrop' Engine Recorder	M. Longridge	Engineering	XXXVII. 431	1884	—
Controlling the Speed of Steam Engines	Anonymous	Engineering	—	—	—
Moscrop's Speed Recorder	Anonymous	Engineering	XXXIX. 483	1885	—
Deacon's Waste-water Meter	Anonymous	Engineering	XL. 489	1885	—
Draper's Self-recording Instrument	Mr. Draper	Engineering	XL. 535	1885	Recording instruments, barometer, anemometers, thermometers, cloud thermometer, and rain gauge.
Testing Machine with Autographic Recording Apparatus	Anonymous	Engineering	XLI. 180	1886	Stress strain diagrams.
Description of an Instrument Intended to Analyse Rolling of Ships at Sea	Vice-Admiral E. Paris	Trans. Inst. Nav. Arch.	XXVII. 284	1886	—

Autographic Test Recorder	H. Wicksteed	Proc. Inst. Mech. Engs.	— 27	1886	—
Apparatus for Time Diagrams of the Action of Continuous Brakes	Anonymous	Engineering	XLIII. 268	1887	—
Ewing's Seismographs	Anonymous	Engineering	XLIII. 519	1887	—
Worthington Pumping Engine	Prof. W. C. Unwin	Engineer	LXVI. 469	1888	Indicator diagram.
Worthington Pumping Engine	Prof. W. C. Unwin	Engineer	LXVI. 491	1888	Trials of, and indicator diagrams.
Surface Condensing Pumping Engine	Anonymous	Engineer	LXVI. 521	1888	Indicator diagram.
Davey's Expansive Working Pumping Engine	Anonymous	Engineering	XLV. 390	1888	Indicator diagrams.
Electric Water Level	Anonymous	Engineer	LXVI. 493	1888	Record by instrument.
Barr and MacWhirter's Electric Water Level	D. Baird	Trans. Mining Engs. Scot.	X.	1888–9	Hydraulic indicator.
Deacon's Water Meter	Anonymous	Engineer	LXVII. 363	1889	—
Tabor Indicator	Anonymous	Engineer	LXVIII. 50	1889	—
Ewing's Duplex Seismographs	Anonymous	Engineering	XLVII. 180	1889	—
The Alexander-Thomson Moment Delineator	Prof. T. Alexander, A. W. Thomson	Trans. Inst. Engs. Shipbuilders Scot.	XXXIII.	1889–90	Diagram.
Engine Speed Register Experimental Van	Anonymous	Engineering	XLVIII. 389	—	Curves of pull and travel.
Edinburgh Electrical Exhibition	Anonymous	Engineer	LXX. 125	1890	Ampère per hour recorder.
Addington's Pumping Engines	Prof. A. B. W. Kennedy	Engineer	LXX. 167	1890	Efficiency diagrams.
Water Velocity and Quantity Recorder	A. C. Hurtzig, W. H. Bailey	Engineer	LXX. 278	1890	—
Water Velocity and Quantity Recorder	W. Restler	Engineer	LXX. 376	1890	Patterson's recorder.
Bachelder Steam Engine Indicator	Anonymous	Engineer	LXX. 527	1890	—
Apparatus for Registering the Oscillation of Locomotives	Anonymous	Engineering	XLIX. 47	1890	—
A New Integrator	Prof. K. Pearson	Engineering	XLIX. 130	1890	—
Amsler's Recording Instrument	Anonymous	Engineering	L. 497	1890	—
Experiments on a Capell and Schiele Fan	M. Deacon	Trans. Chesterfield and Midland Inst. Engs.	XVIII.	1890	Indicator diagrams.
Medium Fan	A. Lupton	Proc. Midland Inst. Mining Engs.	July 22	1890	Applying Richard's indicator velocimeter.
Compound Direct-acting Self-governing Pumping Engine	Anonymous	Engineering	L. 528	1890	Diagrams.
Worthington Compound.	Anonymous	Engineer	LXXI. 215	1891	Curves of pressure
Worthington Compound.	Anonymous	Engineer	LXXI. 244	1891	Rate of working, &c.

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Bristol's Recorder Pressure Gauge.	Anonymous.	Engineer	LXXI. 73	1891	—
Balancing of Marine Engines, Vibrations of Vessels	A. F. Yarrow	Marine Engineer	XIV. 158	1892	Vibrometer.
Howlett's Patent Anemograph	S. B. Howlett	New Series of the Prof. Corps of Roy. Engs.	XV., XVI.	1866, 1868	—
EARTHWORK QUANTITIES.					
Diagrams of Bridge Quantities	Anonymous.	Engineering	V. 209	1868	—
Computation of Earthwork	Lars Lys-Gaard	Engineering	VII. 378	1869	—
Estimating Earthworks.	J. R. Gilliss.	Engineering	VIII. 188	1869	—
Diagram of the Computation of Earthwork	J. A. C. Branfill	Engineering	XXV. 159	1878	—
ELECTRICITY AND MAGNETISM.					
Phenomena of Terrestrial Magnetism	Major E. Sabine	Rep. Brit. Assoc.	IV. 61	1835	Isogonic lines of equal magnetic variation.
Phenomena of Terrestrial Magnetism	Major E. Sabine	Rep. Brit. Assoc.	VI. 97	1836	Magnetic chart.
Phenomena of Terrestrial Magnetism	Major E. Sabine	Rep. Brit. Assoc.	VII. 1	1837	Magnetic chart.
Electrical Observations at Kew	W. R. Birt	Rep. Brit. Assoc.	XIX. 113	1849	—
Combined Motions of the Magnetic Needle	J. A. Brown	Proc. Roy. Soc. Edinb.	II.	1850	—
The Electric Telegraph	F. R. Window	Proc. Inst. C.E.	XI. 329	1851–2	Quantities of electricity and length of wire.
Submarine Cables	S. A. Varley	Proc. Inst. C.E.	XVII. 368	1857	Tension curves.
Submarine Circuit.	Anonymous.	Engineer	VI. 448	1858	Tension curves.
Submarine Telegraphy	S. A. Varley	Engineer	VII. 256	1859	Curve of current waves in cables.

Electrodynamic Induction	G. Blair	Engineer	VII. 407	1859	—
Electrodynamic Induction	G. Blair	Engineer	VII. 425	1859	E.M.F. curves.
Electrodynamic Induction	Anonymous	Engineer	VIII. 6	1859	E.M.F. curves.
Molecular Structure and Magnetic Distribution in Iron	P. Cameron	Engineer	XVII. 1	1864	Lines of force.
Malta and Alexandria Telegraph	C. W. Siemens	Proc. Inst. C.E.	XXI. 1	1865	Diagram of insulation.
Atlantic Telegraphic Volta-electric Induction	Anonymous	Engineering	II. 317	1866	Curves of induced current form.
Atlantic and other long Cables	C. F. Varley	Engineer	XXIII. 169	1867	Strength of current.
Electric Resistance of Iron at High Temperatures	C. M. Smith, C. G. Knott, A. Macfarlane	Proc. Roy. Soc. Edinb.	VIII.	1872–5	
Laboratory Notes on Thermo-electricity	Prof. P. G. Tait	Proc. Roy. Soc. Edinb.	VIII.	1872–5	—
The Flow of Electricity in Conducting Surfaces	W. R. Smith	Proc. Roy. Soc. Edinb.	VIII.	1872–5	—
The Effect of Heating the Pole of a Magnet	D. H. Marshall	Proc. Roy. Soc. Edinb.	VIII.	1872–5	—
Electrolysis	A. Tribe	Proc. Roy. Soc. Lond.	XXIV. 308	1875–6	—
Diamagnetic Rotation	S. Forbes	Proc. Roy. Soc. Edinb.	IX.	1875–8	—
Recent Improvements in Dynamo-electric Apparatus	R. W. Paget-Higgs, J. R. Brittle	Proc. Inst. C.E.	LII.	1877–8	Actinic value of light.
Electric Lighting	Dr. J. Hopkinson	Engineer	XLVII. 349	1879	Characteristics.
Electric Lighting	Dr. J. Hopkinson	Engineering	XXVII. 403	1879	Curve connecting E.M.F. and current.
Magnetic Lines of Force in Magnets	R. C. Shettle	Proc. Roy. Soc. Lond.	XXIX. 102	1879	Lines of force.
Dynamo-electric Machines	Anonymous	Engineering	XXIX. 154	1880	—
Electric Lighting	Dr. J. Hopkinson	Engineering	XXIX. 424	1880	Curves of force and current.
Shaping of Armature	R. H. Ridout	Engineer	XLIX. 42	1880	Face and edge of armature.
Electric Lighting	Dr. J. Hopkinson	Engineer	XLIX. 312	1880	Characteristics.
Effect of the Electrical Discharge on a Flame	Dr. A. Macfarlane, M. D. Rintoul	Proc. Roy. Soc. Edinb.	XI.	1880–2	—
Atmospheric Electricity	G. M. Whipple	Rep. Brit. Assoc.	LI. 443	1881	Tension curves.
Magnetic Disturbances and Earth Currents	Prof. W. G. Adams	Rep. Brit. Assoc.	LI. 463	1881	Comparison of magnetic elements.
Efficiency of Electric Lamps	Profs. Ayrton and Perry	Engineer	LII. 379	1881	Calibration of ammeter.

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Electric Transmission of Power	Anonymous	Engineering	XXXIII. 3	1882	Velocity and convolutions.
On the Mechanical Production of Electric Current	Anonymous	Engineering	XXXIII. 77, 101	1882	Lines of forces.
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Electric Lighting	A. Jamieson	Trans. Mining Inst. Scot.	IV.	1882–3	Curves of h.p. and candle power.
Electrical Resistance of Glass	T. Gray	Proc. Roy. Soc. Lond.	XXXIV. 199	1882–3	—
On the Measurement of Resistance to Electrolytes	C. G. Knott	Proc. Roy. Soc. Edinb.	XII.	1882–4	—
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Determination of Magnetic Susceptibility	R. Shida	Proc. Roy. Soc. Lond.	XXXV. 404	1883	Intensity of magnetism.
Electrical Resistance of Carbon Contacts	S. Bidwell	Proc. Roy. Soc. Lond.	XXXV. 1	1883	—
E.M.F. and Resistance of Batteries	W. H. Preece	Proc. Roy. Soc. Lond.	XXXV. 48, 251	1883	—
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Accumulators	Dr. O. Lodge	Engineer	LV. 1	1883	Discharge of cell.
Portrush Electrical Railway	A. Siemens, Dr. E. Hopkinson	Engineer	LV. 286	1883	Characteristic.
Dynamo-electric Machinery	F. S. Sprague	Engineer	LVI. 106	1883	Characteristic.
Dynamo-electric Machine	Anonymous	Engineer	LVI. 341	1883	Indicator diagram.
Volta-electric Induction	W. Smith	Engineer	LVI. 380	1883	Reversals per minute.
Volta-electric Induction	W. Smith	Engineer	LVI. 409	1883	Curves of force.
Electric Discharge with Chloride of Silver Battery	W. De la Rue, M.A., Hugo Müller, F.R.S.	Proc. Roy. Soc. Lond.	XXXVI. 151	1883–4	—

Production of Transient Electric Currents	J. A. Ewing .	Proc. Roy. Soc. Lond. .	XXXVI. 117	1883-4	—
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Recent Progress in Dynamo-electric Machinery	Prof. Silvanus P. Thompson	Iron (also Society of Arts)	XXIII.	1884	—
The Electric Lightning at the International Health Exhibition	Anonymous . .	Engineering . . .	XXXVIII. 415	1884	Curves of the degree of illumination.
Philadelphia Electrical Exhibition	C. J. Woodbury .	Engineering . . .	XXXVIII. 530	1884	Curves of h.p. of dynamo and lamps in circuit.
Diurnal Ranges of Magnetic Declination	Prof. B. Stewart, W. Dodgson	Proc. Lit. Phil. Soc. Manch.	VIII. 3rd Series	1884	—
On Unequal Electric Conduction Resistance at Cathodes	G. Gore . .	Proc. Roy. Soc. Lond. .	XXXVII. 35	1884	—
Energy and Radiation in Incandescent Lamps	Capt. Abney, Lt.-Col. Festing	Proc. Roy. Soc. Lond. .	XXXVII. 156	1884	Total radiation.
Voltaic and Magneto-electric Induction	W. Smith . .	Engineer . . .	LVIII. 11	1884	Voltaic and magneto-induction diagrams.
Lighting of Bethnal Green Museum	Anonymous . .	Engineer . . .	LVIII. 111	1884	Induction diagram.
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Theory of Alternating Currents .	J. Hopkinson .	Engineer . . .	LVIII. 435	1884	Curves of E.M.F.
Electrical Governors . . .	P. W. Willans .	Proc. Inst. C.E. . .	LXXXI.	1884-5	E.M.F. and pull of cores.
Apparent Lines of Force on Passing a Current through Water	T. Andrews . .	Proc. Roy. Soc. Edinb. .	XIII.	1884-6	—
Conducting Power of Alloys . .	H. Rainy . .	Proc. Roy. Soc. Edinb. .	XIII.	1884-6	—
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Increase of Electrolytic Polarisation with Time	W. Peddie . .	Proc. Roy. Soc. Edinb. ,	XIII.	1884-6	—
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Dynamometers for Cable-laying .	M. E. Lacoine .	Engineering . .	XXXIX. 174	1885	Measurement of tension.

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Electric Lighting	R. H. Neville	Proc. Inst. Mech. Engs.	376	1885	—
Magnetisation of Steel and Cast Iron and Soft Iron	J. W. Gemmell	Proc. Roy. Soc. Lond.	XXXIX. 374	1885	—
Trouvé's Incandescent Lamp	H. Vivarez	Engineering	XXXIX. 18	1885	Scale of conductivity, &c.
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Life of Incandescent Lamps	—	Engineering	XL. 439	1885	Curves of hot resistance.
Electric Self-induction	Anonymous	Engineering	XLI. 136	1885	Electromotive force.
Edison-Hopkinson Dynamo	Anonymous	Engineer	LIX. 173	1885	Characteristic curve.
Electrical Engineering at the Inventions Exhibition	Anonymous	Engineer	LIX. 406	1885	Characteristic curve.
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Electro-magnetic Induction	H. Barfield	Industries	I. 16	1886	—
Electro-magnetic Induction	H. Barfield	Industries	I. 103	1886	—
Efficiency and Life of Glow Lamps	Julius Mair	Industries	I. 127	1886	Curves of h.p. and burning hours.
Characteristics of Dynamos	G. Hemp	Industries	I. 569	1886	—
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Self-induction of an Electric Current	Prof. D. E. Hughes	Proc. Roy. Soc. Lond.	XL. 450	1886	Resistance curves.
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Magnetic Properties of Alloys of Nickel and Iron	J. Hopkinson, D.Sc.	Proc. Roy. Soc. Lond.	XLVIII. 1	1890	Induction and magnetising force.
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Compound Locomotives	F. W. Webb	Engineering	XXXVI. 126	1883	Indicator diagrams.

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Compound Locomotives	F. W. Webb	Engineer	LVI. 97	1883	Indicator diagrams.
Compound Goods Engines	— Borries	Engineer	LVI. 175	1883	Indicator diagrams.
Gladstone Express	Anonymous	Engineer	LVI. 317	1883	Indicator diagrams.
Details of Tank Locomotive for the Dutch State Railway	Anonymous	Engineering	XXXVIII. 439	1884	Diagram of speed and gradient.
Goods Locomotive for the Central Pacific Railroad	Anonymous	Engineer	LVIII. 239	1884	Crank and revolution diagrams.
Locomotive Crank Axles	Anonymous	Engineer	LVIII. 358	1884	Diagram.
Construction of Locomotive Engines	W. Stroudley	Proc. Inst. C.E.	LXXXI. 76	1884–5	Indicator diagrams.
Locomotive Performances	Anonymous	Engineering	XL. 283	1885	Trial and indicator diagrams.
Compound Locomotives	R. A. Ziese	Engineering	XL. 480	1885	Curves referring to steam pressures, crank and steam admission.
Honigmann Fireless Engine	Anonymous	Engineer	LIX. 60	1885	Curves of temperature.
Compound Locomotives	Anonymous	Engineer	LX. 329	1885	Indicator diagrams.
Compound Locomotives	Anonymous	Engineer	LX. 390	1885	Indicator diagrams.
Cut-off in Compounding	Prof. R. H. Smith	Engineer	LX. 407	1885	Finding points of cut-off ratio of cylinder volumes.
Compounding Locomotives	A. Borodin	Engineering	XLII. 302	1886	Degree of expansion and consumption of water per 1 horse-power
Compounding Locomotives	A. Borodin	Engineering	XLII. 328	1886	Indicator h.p. diagram.
English *v.* American Locomotives	F. C. Smith	Engineering	XLIII. 140	1887	Indicator diagrams.
Locomotives for the Adelaide and Murray Bridge Railway	Anonymous	Engineering	XLIII. 346	1887	Indicator diagrams.
Compound Passenger Locomotive	Anonymous	Engineering	XLIII. 565	1887	Indicator diagrams.
Compound Goods Locomotive	Anonymous	Engineering	XLIV. 323	1887	Indicator diagrams.
Indicator Diagrams from Compound Locomotives	Anonymous	Engineering	XLV. 361	1888	Compound diagrams.
Locomotive Coupling and Rods	Anonymous	Engineer	LXV. 499	1888	Indicator diagrams.
The Compound Principle applied to Locomotives	E. Worthington	Proc. Inst. C.E.	XCVI. 2	1888–9	Indicator diagrams.
Compounding of Locomotives	T. Urquhart	Proc. Inst. Mech. Engs.	— 47	1889	Temperature of lubricator.
Details of Express Passenger Engine, S.E. Railway	Anonymous	Railway Engineer	X.	1889	Indicator diagrams.
Chemins de Fer de l'Etat (Belge)	Anonymous	Railway Engineer	XI.	1889	Diagrams of expansion, &c.
G.E. Railway Express Engine	Anonymous	Railway Engineer	XI.	1889	Indicator diagrams.

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		LOCOMOTIVE ENGINES—*continued.*			
Diagram from a Compound Engine, Michigan Central Railroad	Anonymous	Railway Engineer	XI.	1889	Diagrams and plate.
Working Locomotives with Petroleum Fuel	T. Urquhart	Engineering	XLVII. 131	1889	Cost of working, Inst. Mech. Engs., 1889.
Working Locomotives with Petroleum Fuel	T. Urquhart	Engineering	XLVII. 157	1889	Curves of pressure.
On Compound Locomotives	R. H. Lapage	Engineering	XLVII. 339	1889	Compound indicator diagrams.
Compound Passenger Locomotive	Anonymous	Engineering	XLVII. 601	1889	Compound indicator diagrams.
Locomotive's Tractive Power	Anonymous	Engineer	LXVIII. 102	1889	Tractive force.
Compound Locomotive	Anonymous	Engineer	LXVIII. 143	1889	Compound diagrams.
Express Locomotive, S.E. Railway	Anonymous	Engineer	LXVIII. 491	1889	Indicator diagrams.
Compound Locomotives	T. Urquhart	Engineering	XLIX. 313	1890	Consumption of petroleum.
Bogie for Express Locomotive	Anonymous	Engineering	XLIX. 537	1890	Consumption of petroleum; indicator diagrams.
Compounding of Locomotives	T. Urquhart	Engineer	LXIX. 87	1890	Indicator diagrams.
Compound Express Locomotives	Anonymous	Engineer	LXIX. 185	1890	Compound diagrams.
Locomotive Practice in America	Anonymous	Engineer	LXIX. 451	1890	Compound indicator diagrams.
Tests of a Compound Locomotive	Anonymous	Engineer	LXX. 249	1890	Indicator diagrams.
Design of Locomotive Cylinders	J. H. Barker	Proc. Inst. C.E.	CVI. 300	1890–1	Indicator diagrams; crank-pin effort.
Caledonian Engine	Anonymous	Engineer	LXXI. 201	1891	Curves of speed.
		MARINE ENGINES.			
SS. 'Nautilus'	Anonymous	Engineer	III. 482	1857	Indicator diagram of force pump.
Surface Condensation in Marine Engines	E. Humphreys	Proc. Inst. Mech. Engs.	— 99	1861	Indicator diagrams.
U.S. Steamer 'Michigan'	Anonymous	Engineer	XIII. 277	1862	Indicator diagrams.
Three-cylinder Expansive Engines	F. W. Wymer	Engineer	XVI. 20	1863	Crank-pin diagrams.
Marine Engines U.S. Navy	Anonymous	Engineer	XXII. 447	1866	Indicator diagrams.
Engines for Twin Screw Launch Ship	Anonymous	Engineering	III. 502	1867	Indicator diagrams.
H.M.S. 'Nymph'	Anonymous	Engineer	XXIII. 547	1867	Indicator diagrams.

SS. 'Mystery'	Anonymous	Engineer	XXIV. 284	1867	Indicator diagrams.
Engines of the 'Wampanoag'	Anonymous	Engineering	V. 409	1868	Indicator diagrams.
Engines of H.M.S. 'Sirius'	Anonymous	Engineering	VI. 459	1868	Indicator diagrams.
SS. 'Honfleurs and Rennes'	Anonymous	Engineer	XXV. 316	1868	Indicator diagrams.
Grasshopper Engines of H.M. Tug 'Manly'	Anonymous	Engineer	XXVI. 190	1868	Indicator diagrams.
Engines of the Screw Steam-tug 'Era' Trials	Anonymous	Engineering	VIII. 241	1869	Indicator diagram.
Twin Screw Marine Engine	Anonymous	Engineer	XXVII. 8	1869	Compound indicator diagram.
SS. 'König Wilhelm'	Anonymous	Engineer	XXVII. 156	1869	Compound indicator diagram.
SS. 'Hindostan'	Anonymous	Engineer	XXVII. 296	1869	Compound indicator diagram.
Steamship 'Performance'	W. G. Bergius	Engineer	XXVIII. 79	1869	Coal per I.H.P. per hour.
Trial trips of SS. 'Europe'	Anonymous	Engineer	XXVIII. 240	1869	Indicator diagram.
Compound Marine Engines	Anonymous	Engineer	XXVIII. 332	1869	Indicator diagrams.
Ocean Steam Navigation	J. Grantham	Proc. Inst. C.E.	XXIX. 126	1869–70	Compound diagram.
Compound Marine Steam Engine	A. Rigg	Trans. Inst. Nav. Arch.	XI. 136	1870	Crank effort diagram.
Compound Engines of the Steamship 'Sin Nanzing'	Anonymous	Engineering	IX. 219	1870	Indicator diagrams.
Perkins High-pressure Marine Engines	Anonymous	Engineering	IX. 258	1870	Indicator diagrams.
Compound Marine Engines	A. Rigg	Engineering	IX. 288	1870	Indicator diagrams.
Compound Marine Engines	A. Rigg	Engineering	IX. 305	1870	Indicator diagram and crank effort diagrams.
Compound Marine Engines	Anonymous	Engineering	IX. 404	1870	Indicator and crank diagram.
Crichton Surface Condenser for Steam Launches	Anonymous	Engineering	X. 23	1870	Indicator diagram.
Engines of the Steamship 'Fairy Dell'	W. Hartnell	Engineering	XI. 155, 198	1871	Compound indicator diagrams.
Compound Engines of the Steamship 'Sir Bevis'	Anonymous	Engineering	XII. 423	1871	Compound indicator diagrams.
Compound Screw Engines, 50 H.P.	Anonymous	Engineer	XXXII. 40	1871	Compound indicator diagrams.
Engines of H.M.S. 'Coquette'	Anonymous	Engineering	XIII. 143	1872	Indicator diagrams.
Perkins Compound Marine Engine	Anonymous	Engineering	XIV. 177	1872	Indicator diagrams.
Engines of the Steamship 'Thorwaldsen'	Anonymous	Engineering	XIV. 221	1872	Indicator diagrams.
Steam Yacht 'Miranda'	Anonymous	Engineer	XXXIII. 280	1872	Indicator diagrams.
H.M.S. 'Minotaur'	Anonymous	Engineer	XXXIII. 412	1872	Steam chart.
On Marine Propulsion	W. R. Eckart	Engineer	XXXIV. 125	1872	Dynamometer chart.

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		MARINE ENGINES—*continued.*			
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SS. 'Cheben'	Anonymous	Engineer	XXXVI. 202	1873	Indicator diagrams.
The Steamship 'Propontis'	Anonymous	Engineering	XVII. 281	1874	Indicator diagrams.
Engines of the Royal Swedish Gunboat 'Ulf'	Anonymous	Engineering	XVII. 407	1874	Indicator diagrams.
Trial of H.M.S. 'Jumna'	Anonymous	Engineering	XVIII. 136	1874	Indicator diagrams.
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The Steamship 'Ferdinand Vandertaelen'	Anonymous	Engineering	XVIII. 250	1874	Indicator diagrams.
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SS. 'African'	Anonymous	Engineer	XXXVII. 100	1874	Compound diagrams.
SS. 'Propontis'	Anonymous	Engineer	XXXVII. 298	1874	Compound diagrams.
SS. 'Ly-Ee-Moon'	Anonymous	Engineer	XXXVIII. 236	1874	Compound diagrams.
Compound Engines	Anonymous	Engineer	XXXVIII. 326	1874	Crank-effort diagrams.
Three-throw Crank Engines of the Compound System	G. B. Rennie	Trans. Inst. Nav. Arch.	XV. 156	1874	Expansion curve.
On the Method of Testing Steam Engines	G. P. Hunt, G. Skeel	Engineering	XIX. 257	1875	Indicator diagrams.
Trials of Screw Steamships	W. Denny	Engineering	XX. 311	1875	Curves of revolutions, &c.
Marine Engines	Anonymous	Engineer	XXXIX. 366	1875	Indicator diagrams.
Compound Engines	R. Sennett	Trans. Inst. Nav. Arch.	XVI. 91	1875	Curves of twisting moment.
Our Indian Troopships	Anonymous	Engineering	XXI. 164	1876	Indicator diagrams.
American Steamship Line	Anonymous	Engineering	XXII. 64	1876	Indicator diagrams.
Gallatin Experiments	C. H. Loring	Engineer	XLI. 130	1876	Indicator diagrams.
Ratio of Indicated to Effective Horse-power	W. Froude	Engineer	XLI. 289	1876	Horse-power and speed.
Resistance of Long and Short Ships	W. Froude	Engineer	XLI. 291	1876	Horse-power and resistance.
SS. 'City of Vera Cruz'	Anonymous	Engineer	XLII. 272	1876	Compound diagrams.
SS. 'Britannic'	Anonymous	Engineer	XLII. 296	1876	Compound diagrams.

Ratio of Indicated to Effective Horse-power	W. Froude . .	Trans. Inst. Nav. Arch. .	XVII. 167	1876	Friction resistance and velocity.
Three-throw Crank Engines of the Compound System	J. R. Ravenhill .	Trans. Inst. Nav. Arch. .	XVII. 212	1876	Compound diagrams.
Trials of Simple and Compound Engines	R. Sennett . .	Trans. Inst. Nav. Arch. .	XVII. 283	1876	Compound diagrams.
Commercial Marine Steam Fleet .	J. R. Ravenhill .	Engineering . . .	XXIV. 208	1877	Indicator diagrams (Inst. N.A.).
Ironclad 'Memdouhiye' . .	Anonymous . .	Engineer . . .	XLIII. 65	1877	Indicator diagram.
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Single and Twin Screws . .	W. H. White .	Engineering . . .	XXV. 329	1878	Speed of ships and indicated horse-power.
The Steamship 'Houssa' . .	G. W. Jaffrey .	Engineering . . .	XXVI. 55	1878	Curves of indicated horse-power and speeds.
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SS. 'Grangemouth' . . .	Anonymous . .	Engineer . . .	XLV. 129	1878	Compound diagrams.
Channel Twin Steamer . . .	Anonymous . .	Engineer . . .	XLV. 197	1878	Indicator diagrams.
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The Indus General Steam Navigation Co. Steamer 'Tezpore'	Anonymous . .	Engineering . . .	XXVII. 276	1879	Indicator diagrams.
H.M. Steel Corvette 'Iris' . .	Anonymous . .	Engineering . . .	XXVII. 306	1879	Curves of bending moment and buoyancy.
Steam Trial of H.M.S. 'Iris' . .	J. Wright . .	Engineering . . .	XXVII. 331	1879	Curves of speed, thrust, and horse-power.
Yarrows's Torpedo Boat . .	Anonymous . .	Engineering . . .	XXVIII. 308	1879	Curves of indicated horse-power, thrust, &c.
The Speed of Steam Vessels . .	R. Mansel . .	Engineering . . .	XXVIII. 466	1879	'Iris' trials.
SS. 'Orient'	Anonymous . .	Engineer . . .	XLVIII. 241	1879	Compound diagrams.
SS. 'Wanderer'	L. Perkins . .	Engineer . . .	XLVIII. 364	1879	Compound diagrams.
SS. 'Wanderer'	L. Perkins . .	Engineer . . .	XLVIII. 415	1879	Compound diagrams.
Steam Trials of H.M.S. 'Iris' .	J. Wright . .	Trans. Inst. Nav. Arch. .	XX. 117	1879	Revolutions and horse-power.
Failure of Crank Shafts in Marine Engines	J. T. Milton .	Trans. Inst. Nav. Arch. .	XX. 180	1879	Twisting moment curves.
Engines of the Yacht 'Wanderer' .	Anonymous . .	Engineering . . .	XXIX. 126	1880	Compound diagrams.
The Steamship 'Arizona' . .	Anonymous . .	Engineering . . .	XXX. 233	1880	Indicator diagrams.
Torpedo Boat Engine . . .	Anonymous . .	Engineering . . .	XXX. 244	1880	Consumption of fuel and heating curves.
Notes on the Trial Data of Screw Steamships	R. Mansel . .	Engineering . . .	XXX. 453	1880	Curves of speed and coefficients.
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Notes on the Trial Data of Screw Steamships	R. Mansel	Engineering	XXX. 533	1880	Revolutions and speed.
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SS. 'Anthracite'	Anonymous	Engineer	L. 91	1880	Compound diagrams.
SS. 'Cora Maria'	Anonymous	Engineer	L. 136	1880	Compound diagrams.
Steam Yacht 'Wanderer'	Anonymous	Engineer	L. 444	1880	Compound diagrams.
Crankshafts	J. T. Milton	Trans. Inst. Nav. Arch.	XXII. 166	1881	Twisting moment curves.
Influence of Cut-off and Length of Stroke on Steam Engines	C. E. Stromeyer	Trans. Inst. Nav. Arch.	XXII. 174	1881	Mean normal pressures stroke.
Compound Oscillating Engines of the 'Prinses Elizabeth,' 'Prinses Marie'	Anonymous	Engineering	XXXI. 219	1881	Compound diagrams.
Compound Engines of the Yacht 'Wanderer'	Anonymous	Engineering	XXXI. 444	1881	Compound diagrams.
The Steamship 'Assyrian Monarch'	Anonymous	Engineering	XXXI. 641	1881	Compound diagrams.
Compound Marine Engines with three Cylinders and two Cranks	R. Douglas	Trans. Inst. Shipbuilders Scot.	XXV.	1881–2	Compound diagrams.
Description of a Composite Screw Tug-boat	J. A. Thompson	Proc. Inst. C.E.	LXX.	1881–2	Indicator diagrams.
Triple Expansion Engines of the Steamship 'Aberdeen'	A. C. Kirk	Engineering	XXXIII. 529	1882	Compound indicator diagrams.
Compound Marine Engines	J. S. van Veen, H. M. van Aadel	Engineering	XXXIII. 579	1882	Compound indicator diagrams.
On Progressive Trials	J. H. Biles	Engineering	XXXIII. 591	1882	Curves showing the method of determining the tidal curve and log rate, &c.; curves of indicated horse-power of steamship 'Spartan.'
SS. 'Claremont'	Anonymous	Engineer	LIV. 82	1882	Compound diagrams.
SS. 'Leerdam'	Anonymous	Engineer	LIV. 214	1882	Compound diagrams.
Triple Expansion Engines SS. 'Aberdeen'	A. C. Kirk	Trans. Inst. Nav. Arch.	XXIII. 33	1882	Compound diagrams.
Compound Engines	W. Parker	Trans. Inst. Nav. Arch.	XXIII. 38	1882	Compound diagrams.
Triple Expansion Engines of the Steamship 'Isle of Dursey'	Anonymous	Engineering	XXXVII. 181	1884	Compound diagrams; curves of strain due to high, low, and intermediate pressure.

Triple Expansion Engines	Anonymous	Engineering	XXXVII. 523	1884	Compound diagrams.
Twin Screw Triple Expansion Engines of the Steamship 'Arabian'	Anonymous	Engineering	XXXVIII. 84	1884	Compound diagrams.
Engines for the German Despatch Vessel 'Blitz'	Anonymous	Engineering	XXXVIII. 200	1884	Indicator diagrams.
Engines of the United States Fish Commission Steamer 'Albatross'	Anonymous	Engineering	XXXVIII. 357	1884	Compound diagrams and curve of twist.
Engines of the Steamship 'County of Salop'	Anonymous	Engineering	XXXVIII. 566	1884	Compound diagrams.
H.M. Cruiser 'Amphion'	Anonymous	Engineer	LVIII. 461	1884	Indicator diagrams.
Triple Expansion Engines	R. A. Ziese	Engineering	XXXIX. 224	1885	Compound diagrams.
Triple Expansion Engines of the Steamship 'Sobralense'	Anonymous	Engineering	XXXIX. 675	1885	Compound diagrams.
Tugs 'Hibernia' and 'Columbia'	Anonymous	Engineer	LIX. 81	1885	Crank effort diagrams.
SS. 'Eastwood' Triple Expansion Engines	Anonymous	Engineer	LX. 11	1885	Compound diagrams.
Triple Compound Engines	A. E. Seaton	Trans. Inst. Nav. Arch.	XXVI. 141	1885	Crank efforts; compound diagram
Engines of the 'Rionnag Na Mara'	Anonymous	Engineering	XLI. 361	1886	Compound diagrams.
Triple and Quadruple Marine Engine Trials	Anonymous	Engineering	XLI. 337	1886	Compound diagrams.
Engines of the Steamship 'Westmoreland'	Anonymous	Engineering	XLII. 63	1886	Compound diagrams.
Progress of Marine Engineering	W. Parker	Engineering	XLII. 122	1886	Curve of ideal efficiency (Inst. N.A.).
Marine Engines of the 'Stepney' and 'Wapping'	Anonymous	Engineering	XLII. 290, 470	1886	Indicator diagrams.
Triple Expansion Marine Engines	R. Wyllie	Engineering	XLII. 495	1886	Compound and twisting moment diagram (Inst. Mech. Engs., 1886).
SS. 'Prometheus'	Anonymous	Engineer	LXI. 186	1886	Compound diagrams.
SS. 'Coot'	Anonymous	Engineer	LXI. 299	1886	Compound diagrams.
Compound Yacht Engines	Anonymous	Engineer	LXI. 488	1886	Indicator diagrams.
Marine Engineering	W. Parker	Engineer	LXII. 106	1886	Compound diagrams.
Triple Expansion Marine Engine	R. Wyllie	Engineer	LXII. 363	1886	Compound diagrams.
Converting Existing Compound into Triple Expansion Engines	H. A. B. Cole	Trans. Inst. Nav. Arch.	XXVII. 319	1886	Compound diagrams, &c., twisting moments.
Progress and Development of Marine Engineering	W. Parker	Trans. Inst. Nav. Arch.	XXVIII. 125	1887	Compound diagrams and efficiency.
Engines of the Steam Yacht 'Gladiator'	Anonymous	Engineering	XLIII. 142	1887	Compound diagrams.

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Triple Expansion Marine Engines	R. Wyllie	Engineer	LXIII. 111	1887	Compound diagrams (Inst. Mech. Engs.).
Triple Expansion Marine Engines	R. Wyllie	Engineer	LXIII. 145	1887	Compound diagrams.
SS. 'Bentinck'	Anonymous	Engineer	LXIII. 287	1887	Compound diagrams.
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Compound Engines for Atlantic Steamers	J. J. Campbell	Engineer	LXIII. 447	1887	Compound diagrams (Liverpool Eng. Soc.).
Compound Engines for Atlantic Steamers	J. J. Campbell	Engineer	LXIII. 471	1887	Compound diagrams.
Triple Expansion Engines of the Steamship 'Maine'	Anonymous	Engineering	XLV. 140	1888	Compound diagrams.
Steam Yacht 'Grace Darling'	Anonymous	Engineer	LXV. 216	1888	Compound diagrams.
Steam Yacht 'Skeandhu'	Anonymous	Engineer	LXVI. 236	1888	Compound diagrams.
SS. 'Hilda'	Anonymous	Engineer	LXVI. 363	1888	Compound diagrams.
Steam Trials Italian Ironclad 'Lepanto'	Major N. Soliani	Trans. Inst. Nav. Arch.	XXX. 113	1889	Efficiency curve.
Marine Engine Performance	Prof. A. B. W. Kennedy	Engineering	XLVII. 528	1889	Indicator diagrams (Inst. Mech. Engs.).
SS. 'Meteor'	Prof. A. B. W. Kennedy	Engineer	LXVII. 380	1889	Compound diagrams.
Nominal Horse-power of Marine Engine Boilers	R. L. Weighton	Trans. North-east Coast Inst. Engs. and Shipbuilders	VI.	1889–90	Piston speed and inertia.
High-speed Engine for Cargo Boats	E. Hall-Brown	Trans. North-east Coast Inst. Engs. and Shipbuilders	VI.	1889–90	Propeller efficiency; temperature; compounding diagrams.
Triple Expansion Engines and Engine Trials at Owens College	Prof. O. Reynolds	Proc. Inst. C.E.	XCIX. 152	1889–90	Indicator diagrams.
A Double-screw Ferry Boat	Anonymous	Engineering	XLIX. 192	1890	Compound and speed diagrams.
Marine Engine Trials	Prof. A. B. W. Kennedy	Engineering	XLIX. 606	1890	Paper read before the Inst. Mech. Engs.
Engines of the Steamship 'Mariposa'	Anonymous	Engineering	XLIX. 754	1890	Indicator diagrams.
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Triple Expansion Engines, SS. 'Vauban'	Anonymous . .	Engineer . . .	LXIX. 473	1890	Compound diagrams.
Compound Marine Engines . .	Anonymous . .	Engineer . . .	LXX. 228	1890	Compound diagrams.
Steam Yacht 'Imogen' . . .	Anonymous . .	Engineer . . .	LXX. 272	1890	Compound diagrams.
Piston-speed and Increased Boiler-pressure in Marine Engines	W. R. Cummins .	Trans. North-east Coast Inst. Engs. and Ship-builders	VII.	1890–1	Indicator diagrams.
An Assistant Cylinder for Marine Engines	D. Joy . . .	Engineering . . .	LI. 431	1891	Indicator diagrams. Read before the Inst. Naval Arch.
The 'City of Paris' . . .	Anonymous . .	Engineering . . .	LI. 560	1891	Compound diagrams.
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Joy's Assistant Cylinder for Marine Engines	J. Thom . .	Engineering . . .	LI. 655	1891	Diagrams on both sides of piston.
The Steamship 'Ophir' . . .	Anonymous . .	Engineering . . .	LII. 593	1891	Compound diagrams.
Engines of the French Torpedo Boat	Anonymous . .	Engineer	LXXI. 84	1891	Compound diagrams.
Joy's Steam Assistant Cylinder .	D. Joy . .	Engineer . . .	LXXI. 113	1891	Indicator diagrams.
Joy's Steam Assistant Cylinder .	D. Joy . . .	Engineer . . .	LXXI. 305	1891	Indicator diagrams (Inst. N.A., 1891).
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SS. 'Sirio,' 'Perseo,' and 'Orione'	Anonymous . .	Engineer . . .	LXXI. 422	1891	Compound diagrams.
H.M.S. 'Philomel' and 'Pearl' .	Anonymous . .	Engineer . . .	LXXI. 466	1891	Compound diagrams.
Trials of SS. 'Iona' . . .	T. Mudd . .	Engineer . . .	LXXI. 516	1891	Admission and temperature and expansion curves.
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Spiel's Patent Petroleum Engines .	Anonymous . .	Engineer . . .	LXIII. 54	1887	Indicator diagrams.
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Spirit Engines	A. F. Yarrow .	Engineer . . .	LXVII. 470	1889	Trials; vapour diagrams.
Petroleum as a Power-producer .	H. G. Harris .	Occ. Papers of the Roy. Engs. Inst.	XVI. 181	1890	Indicator diagrams.
Petroleum Oil Engines . . .	Prof. William Robinson	Engineering . . .	LII. 400	1891	Indicator diagrams (B.A. paper).
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The Liquefaction of Gases	Anonymous	Engineering	XXV. 410	1878	Pressure curve.
Gas-liquefaction Apparatus—Mechanical Refrigeration	J. J. Coleman	Trans. Inst. Engs. Scot.	XXII.	1878–9	—
Air-refrigerating Machines	Anonymous	Engineer	L. 249	1880	Indicator diagrams.
Horizontal Dry Air Refrigerators	Anonymous	Engineer	LI. 349	1881	Indicator diagrams.
Mechanical Refrigeration of Air	T. B. Lightfoot	Engineer	LIV. 71	1882	Diagrams of work done.
Mechanical Refrigeration of Air	T. B. Lightfoot	Engineer	LIV. 80	1882	Diagrams of work done.
Mechanical Refrigeration of Air	T. B. Lightfoot	Engineer	LIV. 126	1882	Diagrams of work done.
Refrigerating Machinery	T. B. Lightfoot	Proc. Inst. Mech. Engs.	— 201	1886	—
Ammonia Refrigerating Machinery	Anonymous	Engineer	XLIII. 89	1887	Indicator diagrams.
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Bodmer's Engines	J. G. Bodmer	Proc. Inst. C.E.	IV. 373	1845	Diagram of cylinder and crank.
Condensation of Steam in Engines and the Improvements to be effected	W. Smith	Proc. Inst. Mech. Engs.	— 31	1850–1	Indicator diagrams.
New Regenerative Condenser for High- and Low-pressure Steam Engines	C. W. Siemens	Proc. Inst. Mech. Engs.	— 20	1851	Indicator diagrams.
Continuous Expansion Steam Engine	J. Samuel	Proc. Inst. Mech. Engs.	— 27	1852	Variations in rotative power.
Description of Six Blast Engines	A. Cowper	Proc. Inst. Mech. Engs.	— 154	1855	Indicator diagrams.
Problem of Balance Weights	Anonymous	Marine Engineer	April 22	1856	—
Steam Engine and Economy of Fuel	A. Morton	Engineer	II. 390	1856	Pressure diagrams.
Steam Engine and Economy of Fuel	A. Morton	Marine Engineer	July 25	1856	—
Steam-power for Agricultural Purposes	W. Waller	Proc. Inst. Mech. Engs.	— 80	1856	Indicator diagrams.
High- and Low-pressure Steam	W. E. Hurst	Engineer	IV. 380	1857	Pressure of steam.
High- and Low-pressure Steam	E. Ingham	Engineer	IV. 456	1857	Pressure of steam.
On Employing Steam Expansively.	A. Morton	Trans. Inst. Shipbuilders Scot.	I.	1857–58	Indicator diagrams.

High- and Low-pressure Steam	F. W. Turner	Engineer	V. 131	1858	Indicator diagrams.
High- and Low-pressure Steam	T. Craddock	Engineer	V. 167	1858	Indicator diagrams.
High- and Low-pressure Steam	Anonymous	Engineer	V. 225	1858	Indicator diagrams.
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High-pressure Condensing Engines	Anonymous	Engineer	V. 260	1858	Indicator diagrams.
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Expansion of Steam	C. Greaves	Engineer	XI. 134	1861	Indicator diagram.
Self-acting Machine for Spooling Thread	W. Wield	Proc. Inst. Mech. Engs.	— 54	1861	Cams performing change movements.
Boiler, Engine, and Surface Condenser	W. May	Proc. Inst. Mech. Engs.	— 94	1861	Indicator diagrams.
Double Cylinder Expansive Steam Engine	W. Pole	Proc. Inst. Mech. Engs.	— 242	1862	Indicator diagrams, &c.
Cowper's Steam Engines	Anonymous	Engineer	XV. 285	1863	Compound diagrams, &c.
Bank-note Printing Machine at the Bank of Ireland	T. Grubb	Proc. Inst. Mech. Engs.	— 166	1865	Indicator diagrams and cam motions.
Corliss Engine	Anonymous	Engineering	I. 186	1866	Indicator diagrams.
Expansive Working	Anonymous	Engineering	I. 214	1866	Indicator diagrams.
The Darby Blowing Engine	Anonymous	Engineering	II. 166	1866	Indicator diagrams.
The Lambeth Waterworks Company	Anonymous	Engineering	II. 275	1866	Indicator diagrams.
Blowing Engines at the Lilleshall Iron Works	Anonymous	Engineering	II. 366	1866	Indicator diagrams.
Diagrams of the Allen Engine	Mr. Mallet	Engineer	XXI. 185	1866	Indicator diagram.
Rotary Engines	G. D. Hughes	Engineer	XXII. 211	1866	Indicator diagrams.
Counterbalancing Winding Engines	J. Daglish	Engineer	XXII. 215	1866	Work done (British Assoc.).
Modern Mining Machinery	Anonymous	Engineer	XXII. 273	1866	Indicator diagrams.
Counterbalancing Reciprocating Engines	F. J. Slade	Engineering	III. 654	1867	—
Ransome & Sims Portable Engine	Anonymous	Engineering	IV. 49	1867	Indicator diagrams.
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Corliss Engine	Messrs. Shepperd Mulliner, Garstang	Engineering	IV. 113	1867	Indicator diagram.
Engine Trials at Bury	W. Hartnell	Engineering	IV. 158	1867	Indicator diagrams.
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Mechanical Ventilator for Mines .	W. Daniel . .	Proc. Inst. Mech. Engs. .	— 317	1875	Indicator diagrams (Inst. N.A.).
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Experimental Engine	B. Donkin	Engineering	XLII. 487	1886	Indicator and heat measurement diagrams.
The Marchant Engine	A. Harris	Engineering	XLII. 557	1886	Indicator diagrams.
Trial of Non-condensing Compound Engines	W. E. Rich, Prof. A. B. W. Kennedy	Engineering	XLII. 559	1886	Trials.
Vertical Tandem Surface Condensing Engine	Anonymous	Engineer	LXI. 31	1886	Compound diagrams.
Cylinder Condensation in Steam Engines	C. L. Gately, A. P. Kletzsch	Engineer	LXI. 84	1886	Percentage condensation.
Condensation of Steam in Cylinders	Anonymous	Engineer	LXI. 171	1886	Compound diagrams.
American Steam Engines	Anonymous	Engineer	LXI. 188	1886	Indicator diagrams.
American Steam Engines	Anonymous	Engineer	LXI. 215	1886	Indicator diagrams.
Condensation of Steam in Cylinders	M. F. FitzGerald	Engineer	LXI. 279	1886	Indicator diagrams.
Triple Expansion Engines	H. A. B. Cole	Engineer	LXI. 335	1886	Indicator diagrams (Inst. Naval Architects).
Reciprocation in High-speed Engine	A. Rigg	Engineer	LXI. 431	1886	Momentum diagrams.
Semi-fixed Engine, 40 Horse-power	Anonymous	Engineer	LXII. 147	1886	Indicator diagrams.
Compound Semi-fixed Engine	Anonymous	Engineer	LXII. 421	1886	Indicator diagrams and trial.
Robey Fixed Engine	Anonymous	Engineer	LXII. 465	1886	Indicator diagrams.
Horizontal Engine, Smithfield Show	Anonymous	Engineer	LXII. 470	1886	Indicator diagrams.
Compound and Triple Expansion Engines	J. P. Hall	Trans. N.E. Coast Inst. Engs. and Shipbuilders	III.	1886–7	Indicator diagrams.
Lincoln Waterworks Engine	H. Teague	Proc. Inst. Mech. Engs.	— 124	1887	—
Friction of Non-condensing Engine at Astley Mills	Anonymous	Industries	II. 396	1887	Indicator diagrams.

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		STATIONARY ENGINES—*continued.*			
Dredging Operations	J. J. Webster	Proc. Inst. C.E.	LXXXIX. 2	1886–7	Indicator diagram.
Vertical Engine	Anonymous	Industries	III. 94	1887	Indicator diagrams.
The Climax Motor	Anonymous	Engineering	XLIII. 296	1887	Indicator diagrams.
Compound Mill Engine	Anonymous	Engineering	XLIII. 495	1887	Indicator and torsion curves and diagrams of link motion.
Governing Mill Engines	H. Kühne	Engineering	XLIII. 554	1887	Indicator and speed diagrams.
Distribution of Heat in the Steam Engine	Major T. English	Engineering	XLIV. 58	1887	Indicator and distribution of heat diagrams.
Distribution of Heat in the Steam Engine	Major T. English	Engineering	XLIV. 103	1887	Condensation and re-evaporation diagrams.
Distribution of Heat in the Stationary Steam Engine	Major T. English	Engineering	XLIV. 387	1887	Curves of distribution of heat (paper read before the Inst. Mech. Engs.).
Triple Expansion Engines	W. P. Mahon	Engineering	XLIV. 537	1887	Indicator diagrams.
Compound Engine	R. Gill	Engineer	LXIII. 70	1887	Indicator diagrams.
Friction of Non-condensing Engine	Prof. R. H. Thurston	Engineer	LXIII. 96	1887	Friction curves and indicator diagrams.
Stationary Steam Engine	Major T. English	Engineer	LXIV. 16	1887	Diagrams of heat (Inst. Mech. Engs.).
Engine Trials, Newcastle	Anonymous	Engineer	LXIV. 43	1887	Indicator diagrams.
Engine Trials, Newcastle	Anonymous	Engineer	LXIV. 104	1887	Indicator diagrams.
Compound Mill Engine, 1,000 Horse-power	Anonymous	Engineer	LXIV. 506	1887	Compound diagrams.
Seller's Compound Engine	Anonymous	Engineer	LXIV. 537	1887	Compound diagrams.
Slide Valve Gears	J. T. Milton	Trans. N.E. Coast Inst. Engs. and Shipbuilders	IV.	1887–8	Zeuner's diagrams.
Trials of Non-condensing Simple, Compound, and Triple Steam Engines	P. W. Willans	Proc. Inst. C.E.	XCIII.	1887–8	Indicator diagrams.
Irrigating Machinery	J. Richards	Proc. Inst. Mech. Engs.	— 33	1888	—
Independent Engines and Stations	W. Lee Church	Electrical Engineer	March 23	1888	—
Semi-portable Engine	Anonymous	Engineering	XLVI. 30	1888	Indicator diagrams.
Heat in the Steam Engine	Prof. D. D. and B. Donkin	Engineering	XLVI. 99	1888	Diagrams of exchange of heat.

Collapsing Pressure of Upright Fire Boxes	J. H. Reed	Engineering	XLVI. 427	1888	Curves of collapsing pressure.
Theoretical and Practical Efficiency of Steam at High Pressure	W. W. Beaumont	Engineering	XLVI. 439	1888	Curves of efficiency (paper read before the British Association).
Horizontal Compound Engine	Anonymous	Engineering	XLVI. 529	1888	Indicator diagrams.
Compound Horizontal Steam Engine	A. A. Crompton	Engineer	LXV. 55	1888	Indicator diagrams.
Heat Engines	R. H. Smith	Engineer	LXV. 89	1888	Indicator diagrams.
Indicator Diagrams	J. W. Beck, J. H. Turner	Engineer	LXV. 214	1888	Indicator diagrams.
Indicator Diagrams	Anonymous	Engineer	LXV. 239	1888	Indicator diagrams and slide-valve diagrams.
Triple Compound Engine	Anonymous	Engineer	LXVI. 72	1888	Indicator diagrams.
Cross Diagrams	D. Kemp	Engineer	LXVI. 73	1888	Indicator diagrams.
Trials of Steam Engines	Anonymous	Engineer	LXVI. 99	1888	Indicator diagrams.
New Steam Engine	H. Turner	Engineer	LXVI. 263	1888	Compound diagrams.
Steam Engine	Professor W. C. Unwin, F.R.S.	Engineer	LXVI. 472	1888	Heat diagrams.
Willans' Triple Expansion	Anonymous	Engineer	LXVI. 501	1888	Indicator diagrams.
Trials of Non-condensing Simple, Compound, and Triple Steam Engines	P. W. Willans	Proc. Inst. C.E.	XCVI.	1888–9	Indicator diagrams.
Velocity Variation of Steam and other Engines	H. B. Ransom	Proc. Inst. C.E.	XCVIII. 357	1888–9	Cyclical and twisting movements.
Four-cylinder Compound Engine, Woolf Type	Anonymous	Railway Engineer	X.	1889	Plate, crank efforts, and diagrams.
The Paxman Steam Engine	Anonymous	Engineering	XLVII. 229	1889	Indicator diagrams.
The Society of Arts Engine Trials	J. Atkinson	Engineering	XLVII. 665	1889	Indicator diagrams.
The Theory of the Steam Engine	Anonymous	Engineering	XLVII. 684, 717	1889	Saturation curves.
Regnault's Experiments on Steam	J. Macfarlane Gray	Engineering	XLVIII. 57	1889	Diagrams.
Regnault's Experiments on Steam	J. Macfarlane Gray	Engineering	XLVIII. 92	1889	—
Regnault's Experiments on Steam	J. Macfarlane Gray	Engineering	XLVIII. 122	1889	Diagrams of temperatures.
Compound Horizontal Engine	Anonymous	Engineering	XLVIII. 277	1889	Diagrams of admission valve.
Steam-jacketed Cylinders	Major T. English	Engineering	XLVIII. 536	1889	Curves of heats &c.
Steam-jacketed Cylinders	Major T. English	Engineering	XLVIII. 556	1889	Indicator diagrams; nett condensation.
Steam-jacketed Cylinders	Major T. English	Engineering	XLVIII. 584	1889	Nett condensation during stroke, &c.

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Trials of Steam Engines, Society of Arts	Anonymous	Engineer	LXVII. 162	1889	Indicator diagrams.
Trials of Steam Engines, Society of Arts	Anonymous	Engineer	LXVII. 178	1889	Indicator diagrams.
Trials of Steam Engines, Society of Arts	Anonymous	Engineer	LXVII. 197	1889	Indicator diagrams.
Davey's Accumulator Engine	Anonymous	Engineer	LXVII. 317	1889	Indicator diagrams.
Turner New Engine	H. Turner	Engineer	LXVII. 462	1889	Indicator diagrams.
Semi-portable Engine	Anonymous	Engineer	LXVII. 525	1889	Indicator diagrams.
Indicator Diagrams	T. P. Rennoldson	Engineer	LXVIII. 94	1889	Compound diagrams.
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Indicator Diagrams	J. J. Campbell	Engineer	LXVIII. 309	1889	Compound diagrams.
Globe Compound Engine	Anonymous	Engineer	LXVIII. 457	1889	Compound diagrams
Reversing Rolling Mill Engine	Anonymous	Engineering	L. 277	1890	Indicator diagrams.
Economy of Small Engines	Anonymous	Engineering	L. 578	1890	Indicator diagrams.
Horizontal Triple Expansion Engine	Anonymous	Engineering	L. 644	1890	Indicator diagrams.
Steam Engine Performances	Prof. M. Schröter	Engineering	L. 669	1890	Compound diagrams.
Combining Indicator Diagrams	E. Hall-Brown	Engineer	LXIX. 79	1890	Indicator diagrams.
Combining Indicator Diagrams	S. Nelson	Engineer	LXIX. 99	1890	Compound diagrams.
Combining Indicator Diagrams	T. P. Rennoldson	Engineer	LXIX. 112	1890	Compound diagrams.
Combining Indicator Diagrams	R. Gill	Engineer	LXIX. 152	1890	Compound diagrams.
Indicator Diagrams	J. Phillips	Engineer	LXX. 403	1890	Compound diagrams.
Balancing High-speed Steam Engines	A. Rigg	Trans. Soc. Engs.	p. 23	1891	Inertia diagrams.
Compound Engine	Sellers	Marine Engineers	XIII. 156	1891	—
Gas *v.* Steam Power	Anonymous	Engineering	LI. 454	1891	Indicator diagrams.
Wolf's Semi-portable Compound Engine	Anonymous	Engineering	LI. 727	1891	Indicator diagrams.
Triple Expansion Engine	Anonymous	Engineer	LXXI. 115	1891	Valve diagrams.
Curious Diagrams	H. E. Bodley	Engineer	LXXI. 317	1891	Indicator diagrams.
Liverpool Motive Power	J. Parry	Proc. Inst. Mech. Engs.	— 32	1892	—
Tests of a Stationary Engine	R. H. Buel	—	XXI. 490	—	Indicator diagrams

Flow of Fluids under Pressure	R. D. Napier	Engineer	XXIII. 11	1867	Velocity curve.
Flow of Gases	T. Baldwin	Engineer	XXVIII. 287	1869	Pressure curve.
The Efflux of Elastic Fluid	J. M. Gray	Engineering	XIII. 220	1872	Escaping steam pressure, &c.
The Efflux of Elastic Fluid	R. D. Napier	Engineering	XIII. 403	1872	Diagram of the discharge of steam.
Elasticity and Density of Vapours	A. Morton	Engineering	XXIV. 38	1877	Curves of elasticity and temperature.
Exhausting Gas	C. Woodall	Engineering	XXIV. 58	1877	Indicator diagrams.

FRICTION (MISCELLANEOUS).

Friction of Marine Engines	T. Adams	Engineer	XIX. 6	1865	Crank efforts.
Friction of Marine Engines	T. Adams	Engineer	XIX. 54	1865	Crank efforts.
Experiments on Friction	Col. H. Clerk	Proc. Roy. Artil. Inst.	VI.	1870	Curves of coefficients.
The Friction of Screws	Anonymous	Engineering	XIX. 73	1875	Resolution of forces.
Friction at High Velocities of Brakes	Capt. D. Galton	Rep. Brit. Assoc.	XLIX. 508	1879	Speed and time.
Lubricating Oils	C. J. H. Woodbury	Engineering	XXXVIII. 533	1884	Curves of friction at various temperatures and pressure.
On the Friction of Shafts or Journals thoroughly Lubricated	W. R. Browne	Engineer	LVIII. 57	1884	Diagram of coefficients of friction.
Sliding Friction of Rotation	R. H. Thurston	Engineer	LVIII. 397	1884	Diagram of friction.
Report on Friction Experiments	B. Tower	Engineer	LVIII. 434	1884	Diagrams of friction experiments.
Friction of Discs Rotated in Fluids	Prof. W. C. Unwin	Proc. Inst. C.E.	LXXX. 221	1884–5	Friction curves.
Friction Experiments	B. Tower	Engineering	XXXIX. 150	1885	Curves of pressure on bearing (Inst. Mech. Engs., 1883–8).
Friction of Marine Engines	Anonymous	Engineering	XLI. 207, 249	1886	Indicator diagrams from the steamship 'Cleveland'
Friction of Different Velocities	Prof. H. S. Hele-Shaw	Engineering	XLI. 458	1886	Coefficients of friction and speed.
Friction in Marine Engines	W. Sisson	Engineering	XLI. 571	1886	Indicator diagrams.
Recent Researches in Friction	J. Goodman	Proc. Inst. C.E.	LXXXIX. 421	1886–7	Frictional resistances.
Roller Friction	Prof. H. S. Hele-Shaw and Edward Shaw	Engineering	XLIV. 198	1887	Curves of pressure between surfaces and corresponding forces.
Experiments on Friction	Report of Search Committee	Engineering	XLV. 467	1888	Friction and load diagrams (Inst. Mech. Engs.).

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Internal Friction of Non-condensing Engines	R. H. Thurston	Engineering	XLV. 2	1888	Diagram of friction and horse-power.
Lubrication	V. Wilson	Engineering	XLV. 379	1888	Diagram of temperature of oils.
Laws of Fluid Friction	R. Snowdon	Industries	VII. 415	1889	Friction and velocity.
Experiments on the Friction of Steam Engines	R. H. Thurston	Engineering	XLVII. 27	1889	Frictional horse-power.
On the Distribution of Internal Friction of Engines	R. H. Thurston	Engineering	XLVII. 47	1889	Friction with change of load, friction with cut-off.
Oil-testing Machines	Anonymous	Engineering	XLIX. 375	1890	Coefficient and temperature of bearing, &c.
Pivot Friction	Report of Search Committee	Engineering	LI. 478	1891	Curves of pivot friction (read before the Inst. Mining Engs., 1891).
		HEAT.			
Cruise of H.M.S. 'Challenger'	Wyville Thomson.	Proc. Roy. Soc. Lond.	XXIV. 462	1875–6	Temperature and soundings.
Coefficients of Expansion	G. F. Rodwell	Proc. Roy. Soc. Lond.	XXXII. 540	1881	—
Methods Employed in Calibration of Mercurial Thermometers	Prof. B. Stewart, Prof. Rücker, Prof. T. E. Thorpe	Rep. Brit. Assoc.	LII. 145	1882	—
Soundings and Temperature in the Faroe Channel	T. H. Tizard	Proc. Roy. Soc. Lond.	XXXV. 202	1883	—
Transmission of Heat	G. A. Hagemann	Proc. Inst. C.E.	LXXVII. 311	1883–4	—
On Sun Spots and Terrestrial Phenomena	Prof. Schuster	Rep. Brit. Assoc.	LIV. 447	1884	Temperature curves.
Mechanical Equivalent of Heat	E. A. Cowper, W. Anderson	Engineer	LXIV. 213	1887	Curves of experiments (British Association).
Heat Expenditure in Steam Engines	Prof. Dwelshauvers Dery	Proc. Inst. C.E.	XCVIII.	1888–9	Heat diagrams.

Indicators.

Improved Steam Indicator	J. Hannon	Trans. Inst. Engs. Shipbuilders Scot.	IX.	1865–6	Diagrams.
Reducing Gear for Steam Engine Indicators	W. Schönheyder	Engineering	IX. 432	1870	—
Computing and Comparing Indicator Diagrams	G. H. Babcock	Engineering	X. 105	1870	Indicator diagrams.
Improvements in the Indicator	L. F. Lyne	Engineering	XXXII. 113	1881	Indicator diagrams.
Steam Indicator	J. M. Ronaldson	Trans. Mining Inst. Scot.	III.	1881–2	Indicator diagrams.
The Crosby Indicator	Anonymous	Engineering	XXXVII. 185	1884	Indicator diagrams.
Theory of Indicator and Errors in Indicator Diagrams	Prof. O. Reynolds	Proc. Inst. C.E.	LXXXIII. 1	1885–6	Indicator diagrams.
Experiments on Steam Engine Indicator	A. W. Brightmore	Proc. Inst. C.E.	LXXXIII. 20	1885–6	Indicator diagrams.
A Strain Indicator for Use at Sea	C. E. Stromeyer	Engineering	XLI. 422	1886	Curve of strain.
Steam Engine Indicator by Mr. Hirn	B. Donkin	Engineering	XLVI. 577	1888	Indicator diagrams.
McInnes Indicator	Anonymous	Engineering	XLVIII. 158	1889	—

Materials, Properties of.

Method of Estimating the amount of Smoke	L. E. Fletcher (Chief Engineer's Report)	Proc. Manchester Steam Users' Assoc.	I. 69	1862–9	Diagram showing method of recording density of smoke.
Iron and Steel	F. Kohn	Engineering	IV. 282	1867	Curves of percentage of carbon (Brit. Assoc. Paper).
Different Methods of Working Coal	P. Cooper	Trans. Inst. Mining Engs.	I.	1869–70	—
Changes of Minerals and Blast Furnace	I. Lowthian Bell	Journ. Iron and Steel Inst.	II.	1871	Heat and quantity of gases.
Amount and Tension of Gas in the Strafford Main Colliery	R. Miller	Trans. Midland Inst. Mining and Mech. Engs.	IV.	1874–6	Diagrams.
Notes on the Oaks Colliery Explosion, December 12, 1866	F. W. Embleton	Trans. Midland Inst. Mining and Mech. Engs.	IV.	1874–6	Diagram of pressures.
Remarks on Mr. Embleton's Diagrams of Observations taken at the Oaks Colliery	F. H. Pearce	Trans. Midland Inst. Mining and Mech. Engs.	IV.	1874–6	—

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Engineering in Sweden	C. P. Sandburg	Proc. Inst. C.E.	XXXIX. 191	1874–5	Curves of prices of iron.
Mechanical Properties of American Car Wheel Irons	Anonymous	Engineering	XIX. 240	1875	Strain diagrams.
On Atmospheric Influence in connection with Colliery Explosions	J. Warburton	Trans. Midland Inst. Mining and Mech. Engs.	V.	1875–7	Diagram of colliery explosion.
Properties of Steel	D. Chernoff	Engineering	XXII. 11	1876–7	Curve of the granularity of steel.
On Separation of Carbon, Sulphur, and Phosphorus	I. Lowthian Bell	Journ. Iron and Steel Inst.	—	1877	Diagram showing loss of carbon.
Iron and Steel Industries in Foreign Countries	Committee	Report on Iron and Steel Industries in Foreign Countries	—	1878	—
Properties of Iron and Steel	D. Adamson	Engineer	XLVI. 204	1878	Fatigue curve.
Mechanical Properties of Iron and Mild Steel	D. Adamson	Journ. Iron and Steel Inst.	—	1879	—
Process for the Dephosphorising of Iron	H. C. Bull	Journ. Iron and Steel Inst.	—	1879	—
Physical Changes of Iron and Steel at High Temperature	T. Wrightson	Journ. Iron and Steel Inst.	—	1879	Instruments; tekometer, afterwards called oncosimeter.
The Dephosphorisation of Pig Iron	M. Pourcel	Engineer	XLVIII. 102	1879	Percentage of impurities.
Dephosphorising in the Converter	J. Massenez	Engineering	XXX. 199	1880	Curve of percentage of impurities.
Physical Changes of Iron and Steel at High Temperatures	T. Wrightson	Journ. Iron and Steel Inst.	—	1880	—
On the Properties of Mild Steel	E. Richards	Engineering	XXXIII. 476	1882	Strain curves.
On the Properties of Mild Steel	E. Richards	Engineering	XXXIII. 502	1882	Tension and compression diagrams.
Properties of Mild Steel	E. Richards	Journ. Iron and Steel Inst.	—	1882	Shear strain and magnetic diagrams.
On the Physical Condition of Iron and Steel	Prof. D. E. Hughes	Engineering	XXXVII. 131	1884	Curves of hardness, tensile strength, and magnetic capacity (Inst. Mining Engs., 1884).

Iron Trade of Scotland . . .	F. J. Rowan .	Inst.			
Scoth and Steel Trade . . .	J. Riley . .	Journ. Iron and Steel Inst.	II.	1885	—
On some Properties of Cast Iron and other Metals	W. J. Millar.	Trans. Inst. Engs. Shipbuilders Scot.	XXIX.	1885–6	—
Removal of Metalloids in the Basic Siemens Process	F. W. Harbord .	Journ. Iron and Steel Inst.	II.	1886	Diagram of basic Siemens-Bessemer process.
On Properties common to Fluid and Solid Metals	W. C. Roberts Austen	Engineering . . .	XLI. 523	1886	Stress strain diagrams.
Some Effects of Quenching and Annealing Mild Steel	Anonymous . .	Engineering . . .	XLII. 228	1886	Stress strain diagrams.
General Principles of Coal Washing	F. J. Rowan .	Trans. Mining Inst. Scot.	IX.	1887–8	—
Discussion on Mr. Waldie's Paper on an Air-agitated Coal-washer	G. A. Mitchell .	Trans. Mining Inst. Scot.	IX.	1887–8	—
Treatment of Mild Steel for Plates	Anonymous . .	Engineering . . .	XLIII. 516	1887	Stress strain diagrams.
Silicon and Silver in Cast Iron .	T. Turner . .	Journ. Iron and Steel Inst.	I.	1888	—
On Manganese Steel . . .	R. A. Hadfield .	Journ. Iron and Steel Inst.	II.	1888	—
The Influence of Sugar on Cement	H. De B. Parsons	Engineering . . .	XLV. 125	1888	Stress strain diagram.
Silica and Sulphur in Cast Iron .	T. Turner . .	Engineering . . .	XLV. 526	1888	Percentage of sulphur in iron (paper read before the Iron and Steel Inst.).
Manufacture of Basic Open Hearth Steel	J. H. Dalby . .	Journ. Iron and Steel Inst.	I.	1889	—
Alloys of Iron and Silicon . .	R. A. Hadfield .	Journ. Iron and Steel Inst.	II.	1889	—
Bessemer's Steel Process . .	F. Lynwood .	Journ. Iron and Steel Inst.	II.	1889	—
Brymbo Steel Works . . .	Anonymous . .	Engineering . . .	XLVII. 536	1889	Curves of the percentage of impurities.
The Influence of Copper on the Tensile Strength of Steel	Anonymous . .	Engineering . . .	XLVII. 582	1889	Percentage of carbon.
Changes in Iron by Thermal Treatment	Dr. J. Hopkinson.	Journ. Iron and Steel Inst.	I. 96	1890	Diagram of tensile strength and magnetic capacity.
Critical Points of Iron and Steel .	F. Osmond . .	Journ. Iron and Steel Inst.	I. 38	1890	Diagrams.
Changes in Iron produced by Thermal Treatment	Dr. E. J. Ball .	Journ. Iron and Steel Inst.	I. 85	1890	Diagram of temperatures.
On Aluminium in Carbonised Iron	W. J. Keep . .	Journ. Iron and Steel Inst.	I. 112	1890	Diagram of deflection and elasticity.

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German Process of Metalling	Dr. H. Wedding	Journ. Iron and Steel Inst.	II.	1890	Diagram of joints and rollers.
Changes in Iron produced by Thermal Treatment	Dr. E. J. Ball	Industries	IX. 218	1890	—
Magnetising Properties of Alloys of Nickel and Iron	Dr. J. Hopkinson	Engineering	L. 293	1890	Diagrams of magnetic force.
Coal Districts, &c., Pennsylvania	H. M. Cadell	Trans. Mining Inst. Scot.	Dec. 21	1891	Diagram of petroleum production.
Graphic Method of Calculating Blast Furnace Charges	H. C. Jenkins	Journ. Iron and Steel Inst.	I.	1891	—
Constituents of Cast Iron	T. Turner	Journ. Iron and Steel Inst.	II.	1891	Relative density and hardness.
On the Illumination of Sulphur from Pig Iron	J. Massenez	Journ. Iron and Steel Inst.	II.	1891	Daily changes from apparatus.
Alloys Research Committee	Prof. W. C. Roberts Austen	Proc. Inst. Mech. Engs.	X. 416	1891	—
Properties of Materials	W. C. R. Austen	Proc. Roy. Soc. Lond.	XLIX. 347	1891	Stress strain diagrams.
Changes in Iron by Thermal Treatment	E. J. Ball	Engineering	LI. 631	1891	Diagram of temperatures.
Properties of Alloys	Prof. W. C. Roberts Austen	Engineering	LII. 580	1891	Curves of cooling.
		MECHANISM.			
Theory of the Crank	Anonymous	Engineer	III. 88	1857	Composition of forces.
Eive's Improved Dynamometer	Anonymous	Engineer	III. 130	1857	Force transmitted.
Shaping Machine	M. Dillon and F. Williams	Engineering	IV. 135	1867	Relative positions of crank pins and fulcrum.
Indicated Horse-power	W. M. Moorsom	Engineering	IV. 203	1867	Diagrams of piston velocity.
Quick Return Motion for Slotting Machines	Anonymous	Engineering	IV. 560	1867	Diagrams of positions of levers.
Parabolic Governor with Moderator	Anonymous	Engineering	VIII. 45	1869	—
Stephenson's Link Motion	C. Falkenburg	Engineer	LV. 396	1883	Diagrams.
Fly Wheels	J. Armer	Engineering	LII. 514	1891	Curves of work absorbed.

METEOROLOGICAL.

Hourly Observation of Thermometer at Plymouth Dockyard	W. Snow Harris .	Rep. Brit. Assoc. . .	V. 181	1835	Temperature curves.
On Waves	Sir J. Robinson, J. Scott Russell	Rep. Brit. Assoc. . ,	VII. 417	1837	Velocity and height of waves.
Progress and State of the Meteorological Observations at Plymouth	W. Snow Harris .	Rep. Brit. Assoc. , .	VIII. 21	1838	Tidal curves.
Progress and State of the Meteorological Observations at Plymouth	W. Snow Harris .	Rep. Brit. Assoc. . .	IX. 149	1839	Tidal curves.
Progress and State of the Meteorological Observations at Plymouth	W. Snow Harris .	Rep. Brit. Assoc. . .	X. 157	1840	Whewell's anemometer.
Terrestrial Magnetism and Meteorology	Sir J. F. W. Herschel, Dr. Whewell, Prof. Lloyd, Lt.-Col. Sabine	Rep. Brit. Assoc. . .	XI. 38	1841	—
Cycle of Eighteen Years of Atmospherical Phenomena	Luke Howard .	Rep. Brit. Assoc. . .	XII. 24	1842	—
Meteorology of Toronto, in Canada	Lt.-Col. E. Sabine	Rep. Brit. Assoc. . .	XIV. 59	1844	—
Atmospheric Waves . . .	W. R. Birt . .	Rep. Brit. Assoc. . .	XIV. 267	1844	—
On Waves	Sir J. Robinson, J. Scott Russell	Rep. Brit. Assoc. . .	XIV. 311	1844	—
Diurnal Variations at Bombay, 1843	Lt.-Col. E. Sabine	Rep. Brit. Assoc. .	XV. 73	1845	—
Atmospherical Disturbance at Bombay	T. Hopkins . .	Proc. Lit. Phil. Soc. Manch.	VIII. 2nd Series	1848	—
Curve of Great Symmetrical Barometrical Wave	W. R. Birt . .	Rep. Brit. Assoc. . .	XVIII. 35	1848	—
Meteorology of Birmingham . .	W. Wills . .	Rep. Brit. Assoc. . .	XXII. 297	1852	—
Meteorological Records of Liverpool	A. F. Osler . .	Rep. Brit. Assoc. . .	XXV. 127	1855	—
Condition of the River Thames .	H. Robinson .	Proc. Inst. C.E. . .	XV. 195	1855-6	Tidal curve.
Meteorology	T. Dobson . .	Rep. Brit. Assoc. . .	XXVI. 31	1856	—
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Stability of Ships at Launching	J. H. Biles	Trans. Inst. Engs. and Shipbuilders Scot.	XXVII.	1883–4	—
New Method of Calculating Stability of Ships	V. Daymard	Trans. Inst. Nav. Arch.	XXV. 57	1884	Stability curves.
Use of Amsler-Laffon's Integrator in Naval Architecture	Dr. A. Amsler	Trans. Inst. Nav. Arch.	XXV. 189	1884	Examples of problems.
Problems on Stability	L. Benjamin	Trans. Inst. Nav. Arch.	XXV. 208	1884	Stability curves.
Graphic Calculation for Ships' Stability	J. C. Spence	Trans. Inst. Nav. Arch.	XXV. 222	1884	Stability curves.
Safety of Well-decked Steamers	T. Phillips	Trans. Inst. Nav. Arch.	XXV. 235	1884	Stability curves.
Torpedo Boats	Anonymous	Engineering	XXXVII. 214	1884	Curves of maximum stability.
Stability of Vessels	F. Elgar	Engineering	XXXVII. 325	1884	Curves of stability (Inst. Nav. Arch., 1884).
Cross Curves of Stability	W. Denny	Engineering	XXXVII. 335	1884	Curves of stability (Inst. Nav. Arch., 1884).
Stability of Vessels	H. Schultz	Engineering	XXXVII. 382	1884	Stability curves.
Stability of Ships	A. E. Long	Trans. N.E. Coast Inst. Engs. and Shipbuilders	I.	1884–5	Cross curves; scale of deplacement.
Twisting Moment on Crank Shafts	R. Sinclair	Trans. N.E. Coast Inst. Engs. and Shipbuilders	I.	1884–5	Moment curves.
Designs of Racing Yachts	A. E. Long, W. E. Paton	Trans. N.E. Coast Inst. Engs. and Shipbuilders	II.	1885–6	Curves of righting levers; effect of heeling upon steering.
Freeboard of Merchant Ships	I. Mavor, T. Millar	Trans. N.E. Coast Inst. Engs. and Shipbuilders	II.	1885–6	Stability; load curves; buoyancy.
Launching of Vessels	H. G. Gannaway	Trans. N.E. Coast Inst. Engs. and Shipbuilders	III.	1886–7	Tipping and buoyancy curves.

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Principle of Work in Relation to the Strength of Structure	H. Foster	Trans. N.E. Coast Inst. Engs. and Shipbuilders	III.	1886-7	Test and torsion diagrams and curves.
Use of Water Chambers for Reducing Rolling of Ships	P. Watts	Trans. Inst. Nav. Arch.	XXVI. 30	1885	—
Stowage of Steamships	F. P. Purvis	Trans. Inst. Nav. Arch.	XXVI. 74	1885	Cubic feet per ton weight and specific gravity.
Arrangement of Coal Bunkers	J. Nicholson	Trans. Inst. Nav. Arch.	XXVI. 98	1885	Displacement.
Strain Indicator for Use at Sea	C. E. Stromeyer	Trans. Inst. Nav. Arch.	XXVII. 33	1886	Strains.
Experiments in Propulsion with Three Screws	M. Marchal	Trans. Inst. Nav. Arch.	XXVII. 232	1886	Power and speed.
Proposed Steam Lifeboat	L. Benjamin, J. M. H. Taylor	Trans. Inst. Nav. Arch.	XXVII. 303	1886	Stability.
New System of Steering Gear and Rudder Strains Recorded by it	A. J. Maginnis	Trans. Inst. Nav. Arch.	XXVII. 358	1886	Curves of rudder strains.
Measurement of Turning Powers of Screw Ships	Capt. P. H. Colomb	Trans. Inst. Nav. Arch.	XXVII. 371	1886	—
Strength of Bulkheads	T. C. Read	Trans. Inst. Nav. Arch.	XXVII. 395	1886	Strength and deflection.
Speed Trials of Recent War-ships	W. H. White	Engineering	XLI. 375	1886	Curves of speed and displacement (Inst. Nav. Arch., 1886).
Steering Gear	A. J. Maginnis	Engineering	XLI. 435	1886	Horse-power; diagram of thrust and rudder strains (Inst. N.A.).
Notes on Losses at Sea	Prof. F. Elgar	Engineering	XLII. 195	1886	Stability curves.
Notes on Losses at Sea	Prof. F. Elgar	Engineering	XLII. 222	1886	Stability curves.
Sea-going Torpedo Boats	Anonymous	Engineering	XLII. 417	1886	Compound diagrams.
Resistance of Ships	Anonymous	Industries	III. 363	1887	Curves of resistance.
Designs of Cruisers	J. H. Biles	Engineer	XLIII. 269	1887	Buoyancy curves.
Losses at Sea	Prof. F. Elgar	Trans. Inst. Nav. Arch.	XXVIII. 53	1887	Righting and heeling moments.
Practical Application of Stability Calculations	A. Denny	Trans. Inst. Nav. Arch.	XXVIII. 375	1887	Speed and power for varying draught.
Recent High-speed Twin Screws	E. A. Linnington	Trans. Inst. Nav. Arch.	XXVIII. 397	1887	Efficiency and slip.
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Strains on Propeller Blades	G. A. Calvert	Engineering	XLIII. 336	1887	Diagram of construction of blade, &c.
Belted and Internal Armour	J. H. Biles	Engineering	XLIII. 359	1887	Buoyancy curves.
Racing and Cruising Yachts	Anonymous	Engineering	XLIV. 554	1887	Diagram indicating relations between the length of beam and sail area.
Remarks on the Speed of Yachts	Anonymous	Engineering	XLIV. 616	1887	Speed diagrams.
Construction of Pontoon Dry Docks	A. Taylor	Trans. N.E. Coast Inst. Engs. and Shipbuilders	IV.	1887–8	Stability curves.
Influence of Coal Consumption on Design of Cargo Ships	R. Thompson	Trans. N.E. Coast Inst. Engs. and Shipbuilders	IV.	1887–8	Profit and distance diagram.
Statistics of Ship-building	Report of the Council	Trans. N.E. Coast Inst. Engs. and Shipbuilders	IV.	1887–8	Tonnage, with years.
'Constant' System of Notation of Result of Experiments on Models used at the Admiralty	R. E. Froude	Trans. Inst. Nav. Arch.	XXIX. 304	1888	Diagram of 'elements of form.'
The 'Zephyr' Launches	Messrs. Yarrow and Co.	Engineering	XLV. 610	1888	Indicator, heat, and spirit evaporation diagrams.
The Italian Ironclad 'Lepanto'	Major N. Soliani	Engineering	XLVI. 194	1888	Curves of resistance, speed, slip, and efficiency.
Dredger for the Suez Canal	Anonymous	Engineer	LXV. 198	1888	Output.
Structional Strength of Cargo Steamers	G. Bergström	Trans. N.E. Coast Inst. Engs. and Shipbuilders	V.	1888–9	Curves of load, buoyancy, strain.
Well-deck Cargo Steamers	G. W. Sivewright	Trans. N.E. Coast Inst. Engs. and Shipbuilders	V.	1888–9	Curves of load, buoyancy, and displacement.
Stability of Oil-carrying Steamers	Prof. P. Jenkins	Trans. Inst. Engs. and Shipbuilders Scot.	XXXII.	1888–9	—
Instruction in Naval Architecture at Glasgow University	Prof. P. Jenkins	Trans. Inst. Nav. Arch.	XXX. 65	1889	Stability curves.
Stability and Metacentric Curves: their Relation	Prof. P. Jenkins	Trans. Inst. Nav. Arch.	XXX. 424	1889	—
Stability of Oil-carrying Steamers	Prof. P. Jenkins	Engineering	XLVII. 571	1889	Curves of stability.
The Dynamite Gun Cruiser 'Vesuvius'	Anonymous	Engineering	XLVII. 653	1889	Diagram of displacement.
Seaworthiness of Torpedo Boats	Lieut. G. W. Hovgaard	Engineering	XLVIII. 103	1889	Curves of stability.
Seaworthiness of Torpedo Boats	Lieut. G. W. Hovgaard	Engineering	XLVIII. 129	1889	Curves of declining angles and curves of rolling.
Seaworthiness of Torpedo Boats	Anonymous	Engineering	XLVIII. 658	1889	Indicator diagrams, horse-power curves, coals per hour, &c.

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Structional Speed of Cargo Steamers of Different Types	G. Bergström	Trans. N.E. Coast Inst. Engs. and Shipbuilders	VI.	1889–90	Curve of strain and stability.
Strength of Ships	Prof. P. Jenkins	Trans. Inst. Nav. Arch.	XXXI. 111	1890	Shearing forces.
Variation of Stresses on Ships at Sea	T. C. Read	Trans. Inst. Nav. Arch.	XXXI. 179	1890	—
Torpedo Boat 'Sunderland' with Petroleum Fuel	Anonymous	Engineering	XLIX. 31	1890	Curves of indicated horse-power, thrust, revolutions, &c.
The Strength of Ships	Prof. P. Jenkins	Engineering	XLIX. 458	1890	Distribution of shearing stress (read before the Inst. Nav. Arch.).
Experiments with Lifeboat Models	J. Corbett	Engineering	XLIX. 519	1890	Curves of stability.
Unsinkability of Cargo-carrying Vessels	H. Hök	Trans. N.E. Coast Inst. Engs. and Shipbuilders	VII.	1890–1	Draught ratio and length of vessel; position and height of bulkheads.
Mechanical Aid in Investigating Experimental Curves	J. D. Young	Trans. N.E. Coast Inst. Engs. and Shipbuilders	VII.	1890–1	Logarithmic scale for powers of numbers.
Ballast Tank Suction in Double-bottom Vessels	G. B. Bruce	Industries	X. 104	1891	(Inst. Nav. Arch., 1891).
Stability of Vessels	J. A. Rowe	Marine Engineer	XII. 155	1891	—
Alterations in Form of Steel Vessels due to Loading	T. Phillips	Trans. Inst. Nav. Arch.	XXXII. 164	1891	Stability curves.
Comparison of Steamers and Yachts	A. E. Jones	Engineering	LII. 1	1891	Diagram of horse-power and speed.
The Construction of Water-tight Bulkheads	Anonymous	Engineering	LII. 386	1891	Curves of space.
An Atlantic Liner	Anonymous	Engineering	LII. 647	1891	Curves of consumption and speed.
		PUMPING ENGINES.			
Experiments on Steam Engines (Cornish Pumping Engine)	Prof. Moseley, E. Hodgkinson, J. S. Enys, Prof. Pole	Rep. Brit. Assoc.	XIV. 90	1844	Diagram of velocity, drawn by chronometrical instrument of Poncelet and Morin.
Horizontal Pumping Engines	E. A. Cowper	Proc. Inst. Mech. Engs.	— 46	1856	Indicator diagram.

Yarmouth Pumping Engine	C. Cowper	Engineer	VI. 120	1858	Indicator diagram and velocity.
Relations of Power and Effect in a Cornish Pumping Engine	C. Greaves	Proc. Inst. Mech. Engs.	— 147	1861	Indicator diagram.
Turbine Water Wheels	J. B. Francis	Engineer	XII. 73	1861	Construction of blades.
Cornish Pumping Engine	W. Howe	Proc. Inst. Mech. Engs.	— 248	1863	Indicator diagrams.
Cornish Pumping Engines	W. Morshead, jun.	Proc. Inst. C.E.	XXIII. 45	1863-4	Indicator diagrams.
Cornish Pumping Engine	A. Fraser	Trans. Soc. Engs.	p. 78	1864	Diagrams of flow and crank effort.
Construction of Turbines	Anonymous	Engineer	XIX. 117	1865	Velocity diagram.
Description of Crossness Pumping Engines	G. Hamilton	Proc. Inst. Mech. Engs.	— 236	1867	—
Combined Centrifugal Pump and Engine	Anonymous	Engineer	XXIV. 297	1867	Indicator diagrams.
Mechanical Ventilation	G. C. Pearce	Engineering	IV. 225	1867	Diagram of pressure and discharge.
Pumping Engines	H. Davey	Engineer	XXIII. 289	1867	Distribution of steam.
Pumping Engines	Anonymous	Engineer	XXIII. 394	1867	Indicator diagram.
Balance Turbines	P. R. Hodge	Engineering	VI. 382	1868	Instrument for drawing curve of blades.
Circulating Pump for Condensers	Anonymous	Engineering	VII. 279	1868–9	Indicator diagrams.
Ventilator	A. L. Steavenson	Engineering	VII. 422	1868–9	Curve of pressure.
Guibal-Lemielle Ventilators	W. Cochrane	Trans. N. Eng. Inst. Mining and Mech. Engs.	XVIII.	1868–9	Water gauge, speed, and indicator diagram.
Mechanical Ventilation	A. L. Steavenson	Trans. N. Eng. Inst. Mining and Mech. Engs.	XVIII.	1868–9	Diagram of useful effect.
Guibal's Ventilating Fan	J. Swindell	Proc. Inst. Mech. Engs.	— 78	1869	—
Pumping Engines for Draining Mines	J. B. Simpson	Proc. N. Eng. Inst. Mining Engs.	XIX.	1869–70	Indicator diagram.
Pumping Engines at the Brooklyn Waterworks	Anonymous	Engineering	IX. 368	1870	Indicator diagrams.
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Pumping Engines at the Berlin Waterworks	Anonymous	Engineering	X. 259	1870	Indicator diagram.
Duty of a Cornish and other Pumping Engines	J. B. Simpson	Trans. Inst. Engs. Shipbuilders Scot.	XIV.	1870-1	Indicator diagram.
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Cornish Pumping Engines	Anonymous	Engineer	XXXI. 69	1871	Indicator diagram.
Direct-acting Steam Pumping	Anonymous	Engineering	XI. 167	1871–2	Indicator diagram.
Air Vessels in Pumping Engines	R. B. Sanderson	Trans. N. Eng. Inst. Mining and Mech. Engs.	XXI.	1871–2	Diagrams of position of plunger.

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Settlingstones Engine	F. W. Hall	Trans. N. Eng. Inst. Mining and Mech. Engs.	XXI.	1871–2	Diagram of force and lifting set.
Guibal Fan Experiments	R. Howe	Trans. Chesterfield and Midland Inst. Engs.	I.	1872–4	Revolutions and horse-power.
Guibal Fan Experiments	Prof. Herschel	Trans. Chesterfield and Midland Inst. Engs.	I.	1872–4	Speed of air and water gauge.
Hydraulic Pumping Engine at Grassmoor Colliery	E. Bromley	Trans. Chesterfield and Midland Inst. Engs.	I.	1872–4	Diagram of supply, &c.
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Differential Expansive Pumping Engine	H. Davey	Trans. Chesterfield and Midland Inst. Engs.	II.	1873–4	Indicator diagram.
Experiments with a Model of Guibal's Fan	Prof. Herschel	Trans. Chesterfield and Midland Inst. Engs.	II.	1873–4	Gauge for speed of air and water.
Coal-cutting Machinery	R. F. Martin	Trans. Chesterfield and Midland Inst.	II.	1873–4	—
Differential Expansive Pumping Engine	H. Davey	Trans. N. Eng. Inst. Mining and Mech. Engs.	XXIII.	1873–4	Indicator diagram.
Pumping Engine at Lynn	Anonymous	Engineer	XXXVIII. 454	1874	Indicator diagrams.
Mine Pumping Engine	H. Davey	Proc. Inst. Mech. Engs.	— 218	1874	Indicator diagram.
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Hydraulic Pumping Engines	H. Davey	Trans. Midland Inst. Mining Engs.	V.	1875–7	Indicator diagram.
Air Compressing Pump	R. Wyllie	Engineering	XXI. 517	1876	—
Cherry's Compound Steam Pumping Engine	Anonymous	Engineering	XXII. 77	1876	—

Ventilating Fan	A. H. Stokes	Trans. Chesterfield and Midland Inst. Engs.		1876–1	Indicator diagram of fan engine, &c.
Root's Mine Ventilators	E. H. Carbutt	Engineer	XLIII. 416	1877	Indicator diagrams.
Compound Pumping Engine, Croydon Waterworks	Anonymous	Engineer	XLIV. 338	1877	Indicator diagrams.
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Rotary Compound Pumping Engine	Anonymous	Engineer	XLV. 59	1878	Indicator diagram.
Greindl Rotary Pump	M. L. Poillon	Proc. Inst. Mech. Engs.	— 440	1878	Theoretical resistance and displacement.
Trial of Pumping Engines	E. D. Leavitt	Engineering	XXVII. 78	1879	Diagrams of pressures.
American Pumping Engines	Anonymous	Engineering	XXVIII. 376	1879	Diagram of boiler pressure.
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Expansion of Steam in Non-rotative Pumping Engines	H. Davey	Rep. Brit. Assoc.	L.	1880	Indicator diagram.
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High-service Pumping Engines at the St. Louis Waterworks	Anonymous	Engineering	XXXI. 200	1881	Indicator diagram.
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The Flensburg Waterworks	Anonymous	Engineering	XXXIV. 494	1882	Indicator and pump diagrams.
Martin's Pumping Engine	Anonymous	Engineering	XXXIV. 623	1882	Indicator and pump diagrams.
Efficiency of Turbines	C. L. Hett	Engineer	LIII. 106	1882	Efficiency.
Leavitt Pumping Engine	J. S. Coon	Engineer	LIII. 188	1882	Indicator diagram.
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Design of De Bay's Ventilator .	J. Nevin . .	Trans. Midland Inst. Mining Engs.	X.	1884	Construction diagram.
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Pumping Engine at the Eastbourne Waterworks	Anonymous . .	Engineering . . .	XXXVIII. 521	1884	Trial indicator diagrams.
Turbines and Screw Propellers .	A. Rigg . .	Engineer . . .	LVIII. 194	1884	Flow of water (Brit. Assoc.).
De Bay's Ventilating Fans . .	W. Fauley . .	Trans. Midland Inst. Mining Engs.	X.	1884–7	Indicator diagram.
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Horse Power of Turbines . .	Prof. R. H. Smith	Engineer . . .	LX. 233	1885	Velocity resolution.
Horse Power of Turbines . .	Prof. R. H. Smith	Engineer . . .	LX. 330	1885	Velocity resolution.
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The Worthington High-duty Pumping Engine	Anonymous . .	Engineering . . .	XLII. 338	1886	Mean velocity and indicator diagram.
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Resistance to Railway Trains	W. Harding	Proc. Inst. C.E.	V. 369	1846	Resistance at different velocities.
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State Railways of India	W. T. Thornton	Proc. Inst. C.E.	XXXV. 214	1872–3	Diagram of traffic increase.
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Swiss Narrow Gauge Railway	Anonymous	Engineering	XX. 70	1875	Construction of rails.
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The Wear of Rails	F. J. Slade	Engineering	XXII. 44	1876	Percentage of failure.
Improvements in the Ranging of Railway Curves	J. Thomson	Trans. Inst. Engs. and Shipbuilders Scot.	XX.	1876–7	—
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		SCREW PROPELLERS.			
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The Screw Propeller (Laing's Helixometer)	J. Laing	Engineer	XIII. 45	1862	Thrust and stability.
Action of the Screw Propeller	J. Howden	Trans. Inst. Engs. and Shipbuilders Scot.	XXI.	1877–8	Displacement curves and slip.
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Dimensions of Screw Propellers	R. E. Froude	Trans. Inst. Nav. Arch.	XXVII. 250	1886	Slip ratio.
Screw Propeller Efficiency	A. G. Greenhill	Engineer	LXI. 426	1886	Pitch, efficiency curves.
Screw Propeller	A. Blechynden	Trans. Inst. N.E. Coast and Engs. Shipbuilders	III.	1886–7	Efficiency; slip friction; speed.
Forces on Screw Propeller Blades	G. A. Calvert	Industries	II. 354	1887	Thrust and velocity.
Recent High-speed Twin Screws	E. A. Linnington	Industries	II. 370	1887	Efficiency and slip.
Slip of Screw Propellers	Anonymous	Industries	II. 454	1887	Slip per cent. and pitch.

Forces acting upon the Blade of a Screw Propeller	G. A. Calvert	Trans. Inst. Nav. Arch.	XXVIII. 303	1887	Pressure and speed.
The Screw Propeller	A. Blechynden	Engineering	XLIII. 459	1887	Diagram of thrust, &c.
Screw Propellers	A. Blechynden	Engineering	XLIII. 557	1887	Efficiency curves; diagram of power expended in friction.
Screw Propeller Efficiency	Prof. A. G. Greenhill	Engineer	LXIII. 141, 205	1887	Diagram of forces; diagram of slip, ratio, and thrust.
Theory of the Screw Propeller	Prof. A. G. Greenhill	Trans. Inst. Nav. Arch.	XXIX. 319	1888	Indicated horse-power and speed.
Experiments on Four- and Two-bladed Screw Propellers	J. B. Andreæ	Trans. Inst. Nav. Arch.	XXIX. 346	1888	Indicated horse-power and speed.
Remarks on Prof. Greenhill's Paper	R. E. Froude	Trans. Inst. Nav. Arch.	XXX. 406	1889	—
Screw Propellers	T. V. Trew	Engineering	XLV. 159	1888	Construction of blade.
Experiments with Screw Propellers	J. B. Andreæ	Engineering	XLV. 373	1888	Slip speed curves, &c. (Inst. Nav. Arch.)
Screw Propeller	N. W. Barnaby	Proc. Inst. C.E.	CII.	1889–90	Trials.
Aluminium Bronze for Screw Propellers	Anonymous	Industries	IX. 304	1890	—
Design of Screw Propeller Blades	Prof. G. F. Fitzgerald	Engineer	LXX. 225	1890	Speed of ships.

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Properties of Steam	Anonymous	Engineer	VIII. 60	1859	Expansion curve.
Efficiency of Steam	W. J. M. Rankine	Engineer	XXI. 1	1866	Indicator diagram.
Mean Pressure of Expanding Steam	W. J. M. Rankine	Engineer	XXI. 261	1866	Graphic method of finding pressure of expanding steam.
Application of the Second Law of Thermodynamics	W. J. M. Rankine	Engineer	XXIV. 85	1867	Indicator diagram.
Working Steam Expansively	Anonymous	Engineer	XXIV. 180	1867	Expansion diagram.
Liquefaction of Steam	W. J. M. Rankine	Engineer	XXV. 122	1869	Indicator diagram.
Steam Engine Coefficients	J. Macfarlane Gray	Engineering	XII. 221	1871	Indicator diagrams.
Steam Engine Coefficients	W. Schönheyder	Engineering	XII. 269	1871	Compound diagrams.
Steam Engine Coefficients	J. Macfarlane Gray	Engineering	XII. 285	1871	Compound diagrams.
Steam Engine Coefficients	Anonymous	Engineering	XII. 375	1871	Indicator diagrams.
Steam Engine Coefficients	J. Macfarlane Gray	Engineering	XII. 406	1871	Indicator diagrams from the steamship 'Bogotá.'

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Steam Expansion Curves	Anonymous	Engineering	XII. 426	1871	Expansion curves.
Steam Engine Coefficients	J. Macfarlane Gray	Engineering	XIII. 8	1872	Compound diagrams.
Clearance and Compression in Steam Cylinders	J. Macfarlane Gray	Engineering	XVII. 241	1874	Indicator diagrams (Inst. N.A.).
Clearance and Compression in Steam Cylinders	Anonymous	Engineering	XIX. 41	1875	Indicator diagrams.
Clearance and Compression in Steam Cylinders	Anonymous	Engineering	XIX. 189	1875	Indicator diagrams.
Ratio of Expansion for Maximum of Efficiency in Steam Cylinders	G. W. Macalpine	Engineering	XIX. 425	1875	—
The Work in a Pound of Steam	Anonymous	Engineering	XXVIII. 439	1879	Diagram of work of condensation.
Cylinder Condensation	G. R. Bodmer	Engineer	LXIII. 179	1887	Diagrams.
Expansion of Steam	J. C. Spence	Industries	II. 447	1887	Graphic methods.
Diagrams of Properties of Water and Saturated Steam	Prof. R. H. Smith	Industries	IV. 426	1888	—
Economy of Low-pressure Steam	Anonymous	Engineer	LXV. 127	1888	Indicator diagrams.
Evaporation	C. Lang	Trans. Inst. Engs. and Shipbuilders Scot.	XXXII.	1888	—
Regnault's Researches on Steam	J. Macfarlane Gray	Engineer	LXVIII. 43	1889	Value of constants.
Experiments on Condensation and Re-evaporation of Steam	T. English, R.E.	Engineer	LXVIII. 399	1889	Indicator diagram; evaporation diagram.
Ether-pressure Theory of Thermodynamics applied to Steam	J. Macfarlane Gray	Trans. Inst. N.A.	XXX. 305	1889	'The thetaphi diagram.'
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		ARCHES.			
Arches	W. H. Barlow	Proc. Inst. C.E.	V. 162	1846	Line of resistance.
Stability of Arches	G. Snell	Proc. Inst. C.E.	V. 439	1846	Line of resistance.
Arched Roofs	C. Wessely	Engineering	I. 155	1866	Line of resistance (Soc. of Eng.).

Theory of Diagrams of Forces as Applied to Roofs and Bridges	J. Clerk Maxwell	Engineering . . .	IV. 235	1867	Reciprocal diagrams (Brit. Assoc. paper).
Straining Action upon Arched Ribs	Prof. W. J. M. Rankine	Engineer . . .	XXV. 2	1868	Diagram of strains.
Iron Arches	W. Airy . .	Engineering . . .	X. 1	1870	Line of resistance.
Iron Arches	W. Airy . .	Engineering . . .	X. 83	1870	Line of resistance.
Iron Arches	W. Airy . .	Engineering . . .	X. 127	1870	Line of resistance.
Metal and Timber Arches . .	J. Gaudard . .	Proc. Inst. C.E. . .	XXXI. 73	1870–1	Bending moment curves.
Braced Arches and Suspension Bridges	Prof. F. Jenkin .	Engineer . . .	XXXI. 98	1871	Strain diagrams.
Stresses of Rigid Arches . .	W. Bell . .	Proc. Inst. C.E. . .	XXXIII. 58	1871–2	Line of resistance.
Strain on Arches	H. P. Bell . .	Engineering . . .	XIII. 289	1872	Diagram of strains.
Upright Arched Bridges . .	Capt. J. B. Eads .	Engineering . . .	XVIII. 291	1874	Diagram of strains.
Upright Arched Bridges . .	Capt. J. B. Eads .	Engineering . . .	XVIII. 330	1874	Diagrams of strains.
Upright Arched Bridges . .	Capt. J. B. Eads .	Engineering . . .	XVIII. 349	1874	Diagrams of strains.
Curve of Equilibrium of a Rigid Arch	G. Fuller . .	Proc. Inst. C.E. . .	XL. 143	1874–5	Curve of resistance.
Reactions of the Supports of an Arched Rib	Anonymous . .	Engineer . . .	XLIV. 454	1877	Diagram of forces.
Cast-iron Arches	Anonymous . .	Engineer . . .	XLV. 285	1878	Force polygons.
On the Directions of the Face Joints of Oblique Arches	J. B. Millar . .	Proc. Lit. Phil. Soc. Manch.	VI. 3rd Series	1879	—
Masonry Arches	Anonymous . .	Engineer . . .	LXII. 63	1886	Curve of equilibrium.
Masonry Arches	Anonymous . .	Engineer . . .	LXII. 87	1886	Curve of equilibrium.
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Equipollent Arches . . .	Anonymous . .	Engineer . . .	LXIII. 144	1887	Curves and length of ordinates.
Tracing Joints of Elliptic Arches .	M. D'Ocagne .	Engineer . . .	LXIII. 355	1887	Line of resistance.
Three-hinged Wrought-iron Arch	J. H. Cunningham	Engineer . . .	LXIV. 136	1887	Stresses, diagram of truss.
The Arch	C. Richardson .	Engineering . . .	XLV. 48	1888	Diagram of forces.
The Arch	A. H. Mason .	Engineering . . .	XLV. 337	1888	Curve of thrusts.
Pressure on Arched Bridges . .	J. Patterson .	Engineering . . .	XLVI. 576	1888	Line of resistance
Pressure on Arch Joints . .	J. C. Trautwine .	Engineering . . .	XLVI. 612	1888	—
Segmental Arches	Prof. T. Alexander	Engineering . . .	XLVIII. 63	1889	Two-nosed catenaries and their application to the design.

BOILERS.

Pressure of the Steam which caused the Explosion of the Boiler on Irk. Locomotive Engine	E. Gibson . .	Proc. Lit. Phil. Soc. Manch.	VII.	1846	—
Locomotive Engine Boilers . .	D. K. Clark .	Proc. Inst. C.E. .	XII. 382	1852–3	Consumption of water.

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The Evaporating Power of Heating Furnace Boilers	F. J. Slade	Engineering	XI. 199	1871	Water evaporated.
Water Tube Marine Boilers	J. Watt	Engineering	XVII. 238	1871	Curve of pressure.
Lackenley Engines and Boilers	A. C. Hill	Proc. Inst. Mech. Engs.	— 274	1872	Diagrams.
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Howard Boiler	D. Joy	Journ. Iron and Steel Inst.	—	1875	Indicator diagram.
Resistance of Boiler Flues to Collapse	Prof. W. C. Unwin	Proc. Inst. C.E.	XLVI. 225	1875–6	Diagram of strength.
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Strength of Boiler Flues	Anonymous	Engineering	XXII. 35	1876	Fairbairn's rule.
Experiments on Howard Boilers	Anonymous	Engineering	XXIII. 81	1877	Curves of pressure and time, &c.
On the Evaporative Power of Locomotive Boilers	J. A. Longridge	Proc. Inst. C.E.	LII.	1877–8	Reduction of temperature diagram.
On Experiments Relative to Steel Boilers	W. Boyd	Engineering	XXV. 321	1878	Curves of buckling tests, &c.
On Experiments Relative to Steel Boilers	W. Boyd	Engineer	XLV. 291	1878	Strength of joints (Inst. Mech. Engs.).
Corrugated Boiler Flues	Anonymous	Engineering	XXIX. 477	1880	—
Boiler Performances	W. Hartnell	Engineering	XXXIII. 299	1882	Curves of heating surface, &c.
Thornycroft's Water Tube Boiler	Anonymous	Engineering	XXXV. 463	1883	Indicator diagram.
Marine Boiler Construction	J. A. Rowe	Trans. N.E. Coast Inst. Engs. and Shipbuilders	I.	1884–5	Percentage of rivets.
Boiler Explosion at Cork	R. Hartland	Engineering	XXXIX. 97	1885	Hypothetical curve of flight.
Boiler Performances	G. H. Babcock	Engineer	LIX. 162	1885	Percentage of moisture.
Steam Boilers	Prof. R. H. Thurston	Engineer	LIX. 506	1885	Curves of available energy.
Boilers of the Steamship 'Westmoreland'	Anonymous	Engineering	XLII. 72	1886	Combined twisting moment.
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Power and Heating Surface	Prof. R. H. Smith	Industries	III. 2	1887	Indicator diagrams.
Power and Heating Surface	Prof. R. H. Smith	Industries	III. 28	1887	Coefficients; graphic table.
Power and Heating Surface	Prof. R. H. Smith	Industries	III. 413	1887	Ratio of expansion.
Helical Joints for Boilers	R. Hartland	Engineering	XLIII. 190	1887	Diagram of relative strength of joints.
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Boilers of the Steamship 'County of York'	Anonymous	Engineering	XLIII. 297	1887	Indicator diagrams.
Helical Joints for Boilers	J. E. Caine	Engineering	XLIII. 380	1887	Diagram of forces.
Helical Joints for Boilers	J. T. Nicolson	Engineering	XLIII. 429	1887	Curves of coefficients.
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Helical Joints for Boilers	J. E. Caine	Engineering	XLIII. 553	1887	Diagrams.
Boiler Experiments and Fuel Economy	J. Holliday	Proc. Inst. C.E.	XCII. 336	1887–8	—
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The Evaporation in Lancashire Boilers	M. Longridge	Engineering	XLIX. 493	1890	Curves of heat evaporation.
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Boiler Experiments	B. Donkin, Prof. Kennedy	Engineering	LI. 236	1891	—
On the Construction of Boilers Adapted to Force Draught	A. F. Yarrow	Engineering	LI. 335	1891	Diagrams of comparative bending of copper and steel boiler extension.

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Taper Chain Tension Bridge	Capt. Goodwyn	Prof. Papers of Corps of Royal Engs.	IX. 83, Old Series	1847	—
Tubular Girder Bridges	W. Fairbairn	Proc. Inst. C.E.	IX. 233	1849–50	Diagrams of deflection.
Lattice Beams	W. B. Blood, W. T. Doyne	Proc. Inst. C.E.	XI. 1	1850–1	Straining forces.
Wrought-iron Beams	J. Barton	Proc. Inst. C.E.	XIV. 443	1854–5	Strain diagrams.
Iron Girders and Tubes	J. M. Heppel	Proc. Inst. C.E.	XV. 155	1855–6	Force diagrams.
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Suspension Bridges	A. S. Lukin, C. E. Conder	Proc. Inst. C.E.	XVI. 458	1856–7	Arrangement of suspension rods.
Iron Truss at Harper's Ferry	I. Kean	Engineer	III. 246	1857	Resolution of forces.
Deflection of Bridges	T. Baldwin	Engineer	VIII. 207	1859	Deflection curves.
Trussed Beams	W. Parsey	Trans. Soc. of Engs.	— 52	1862	—
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Strength of Bridges, Roofs, Arches, Ships	W. E. Kochs	Engineer	XIX. 146	1865	Stresses (Soc. of Engs., 1865).
Proper Depth of Girders	B. Baker	Engineering	II. 261	1866	Diagram of span and level.

Railway Bridge under the Place de l'Europe, Paris	Anonymous .	Engineering . . .	II. 300	1866	Moment of resistances.
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Continuous Girders	Max am Ende	Engineer	LVI. 355	1883	Deflection curves.
Continuous Girders	Max am Ende	Engineer	LVI. 435	1883	Deflection curves.
Continuous Girders	Max am Ende	Engineer	LVI. 479	1883	Deflection curves.
Stresses in Statically Undetermined Systems	Max am Ende	Engineering	XXXVI. 510	1883	—
Loads Fixed on a Beam	Prof. Alexander, Prof. Thomson	Engineering	XXXVII. 513	1884	Link polygon.

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		BRIDGES AND GIRDERS—*continued.*			
Theorem of the Three Moments	Anonymous	Engineer	LVIII. 171	1884	Stress diagram.
Road and Railway Bridge over the River Tessin, Italy	G. Biadgeo	Engineering	XL. 281	1885	Curves of B.M. and S.F.
Launching Continuous Girders	R. Totth	Engineering	XL. 527	1885	Curves of B.M. and S.F.
Blaauw Krantz Bridge	Max am Ende	Engineer	LIX. 200	1885	Resolution of forces.
Blaauw Krantz Bridge	Max am Ende	Engineer	LIX. 298	1885	Resolution of forces.
Estimating Quantities of Girders	Anonymous	Engineer	LIX. 399	1885	Diagram of quantities.
Danube Bridge Project	R. H. Graham	Engineer	LX. 41	1885	Diagram of strains.
Cantilever Bridge at Niagara Falls	C. C. Schneider	Engineering	XIV. 349	1886	Diagram of deflection.
American Iron Bridges	H. Reilly	Engineer	LXI. 241	1886	Diagram of forces.
American Iron Bridges	R. H. Graham	Engineer	LXI. 264	1886	Diagram of forces.
American Iron Bridges	R. H. Smith	Engineer	LXI. 279	1886	Diagram of forces.
American Iron Bridges	W. B. Coventry	Engineer	LXI. 279	1886	Diagram of forces.
Constructional Ironwork	J. J. Webster	Industries	III. 54	1887	Diagonal stresses.
Constructional Ironwork	J. J. Webster	Industries	III. 82	1887	Stress area.
Constructional Ironwork	J. J. Webster	Industries	III. 134	1887	Strength of colun n.
Ravine Bridge, Lowestoft	Anonymous	Engineer	LXIV. 191	1887	Curves of stresses.
New Method of Obtaining Stresses on Lattices	W. Robertson	Engineer	LXIV. 531	1887	Stress diagram.
The Blair Crossing Bridge	Anonymous	Engineering	XLIV. 250	1887	Weight of water in caisson and time.
Vibration of New Tay Bridge	Prof. J. A. Ewing	Proc. Roy. Soc. Lond.	XLIV. 394	1888	Instrument seismograph.
Stresses in Hangers of Lattice Girders	W. Robertson	Engineer	LXV. 211	1888	Bending moments.
Beams	D. K. Clark	Engineer	LXV. 438	1888	Strains.
Beams	D. K. Clark	Engineer	LXV. 497	1888	Strains.
Beams	D. K. Clark	Engineer	LXV. 517	1888	Strains.
Stress Diagrams of Solid Structures	Prof. R. H. Smith	Proc. Inst. C.E.	XCVI. 278	1888-9	—
Central Girders of the Forth Bridge	Anonymous	Industries	VII. 537	1889	Temp. diagrams of Forth Bridge.
Stresses in Crane Posts	F. Garside, Yorks Collian, A. S. Bower	Engineer	LXXI. 127	1891	Force diagrams.

Spacing Cross Girders in Railway Bridges	W. S. MacKenzie.	Engineer	LXXI. 193	1891	Curve of weight.
Stability of Girder Flanges	Max am Ende	Engineer	LXXI. 419	1891	Bending moments.
Stress in a Crane	A. C. Elliott.	Engineer	LXXII. 50	1891	—

Chimneys and Towers.

The Tallest Chimney	Anonymous	Engineering	V. 237	1868	Line of resistance.
Daily Motion of a Brick Tower caused by Heat	A. W. Mackay	Engineer	XXXII. 313	1871	Diagrams.
Strength and Stability of Chimneys	C. A. Evans	Engineer	XXXVII. 37	1874	Resistant forces.
Design of Chimney Shafts	C. Molyneux, J. M. Wood	Industries	III. 60	1887	Line of thrust.
Stability of Chimney Shafts	R. J. Hutton	Trans. Soc. Engs.	— 150	1887	—
Concrete Dam, Beetaloo Waterworks	A. B. Moncrieff	Engineer	LXXI. 362	1891	Lines of resistance.
The Beetaloo Concrete Dam	A. B. Moncrieff	Engineering	LII. 23	1891	Lines of resistance.

Dams and Dock Gates.

Cofferdam and Siphons	J. Hawkshaw	Proc. Inst. C.E.	XXII. 497	1862–3	Tide diagram.
The Closing of Reclamation Banks	J. M. Heppel	Proc. Inst. C.E.	XXIII. 168	1863–4	Graphic integration.
The Resistance of Bodies Passing through Water	G. H. Phipps	Proc. Inst. C.E.	XXIII. 321	1863–4	Curves of resistance.
Continental Dams	Anonymous	Engineer	XXIV. 312	1867	Curves of resistance.
Masonry Dams	M. Delocre	Engineer	XXVI. 34	1868	Resultant forces.
Masonry Dams	M. Delocre	Engineer	XXVI. 57	1868	Resultant forces.
Masonry Dams	M. Delocre	Engineer	XXVI. 75	1868	—
Masonry Dams	M. Delocre	Engineer	XXVI. 91	1868	—
Masonry Dams	M. Delocre	Engineer	XXVI. 113	1868	—
Masonry Dams	M. Delocre	Engineer	XXVI. 131	1868	Lines of resistance.
Design and Construction of Masonry Dams	W. J. M. Rankine	Engineer	XXXIII. 1	1872	Stability curve.
New York Water Supply Dam across the Branch of the Croton River	Anonymous	Engineering	XX. 176	1875	Stability of walls.
Setton's Reservoir	Anonymous	Engineer	XL. 110	1875	Diagram of forces.
Masonry Dam Construction	J. C. Crose	Engineer	XL. 170	1875	Diagram of forces.
Dock Gates	A. F. Blandy	Proc. Inst. C.E.	LVIII. 154	1878–9	Mathematical and load diagram.

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		DAMS AND DOCK GATES—*continued.*			
Strains on Circular Lock Gates	C. H. Romanes	Engineer	LVIII. 383	1884	Diagram of forces.
Strains on Circular Lock Gates	C. H. Romanes	Engineer	LIX. 77	1885	Curves of resistance.
The Vyrnwy Dam	Anonymous	Engineering	XLI. 27	1886	Diagram of forces.
The Vyrnwy Dam	Anonymous	Engineer	LXI. 99	1886	Diagram of forces.
Quaker Bridge Dam	H. B. Church	Engineer	LXV. 327	1888	Composition of pressures.
		LIGHTHOUSES.			
Lighthouse for Capé Canaveral	Anonymous	Engineering	II. 185	1866	Curve of stability.
Strains on Lock Gates	J. E. Williams	Engineering	III. 140	1867	Diagram of strains.
Strains on Lock Gates	Anonymous	Engineering	III. 188	1867	Diagram of forces.
Strains on Lock Gates	Anonymous	Engineering	III. 204	1867	Diagram of bending moment.
		PILES.			
Supporting Power of Piles	W. J. MacAlpine	Proc. Inst. C.E.	XXVII. 275	1867–8	Diagram of pressure.
Pile-driving	Anonymous	Engineer	XLIII. 373	1877	Rate of descent.
Cost of Pile-driving	Anonymous	Engineering	XXIII. 434	1877	Scale of depth driven and time.
		RETAINING WALLS.			
Pressure of Earth against a Retaining Wall	A. C. Elliott	Proc. Roy. Soc. Edinb.	VIII.	—	—
On Retaining Walls	A. Jacob	Engineer	XX. 304	1865	Forces acting.
On the Profiles to be given to Walls Retaining Water	E. L. Asher	Engineering	X. 7	1870	—
On the Profiles to be given to Walls Retaining Water	E. L. Asher	Engineering	X. 19	1870	—
Retaining Walls	T. Higham	Engineering	X. 289	1870	—
Retaining Walls	J. R. Allen	Engineering	X. 419	1870	Line of resistance.
Retaining Walls	J. R. Allen	Engineering	XI. 110	1871	Force diagram.
Different Forms of Retaining Walls	J. S. Tate	Engineer	XXXI. 6	1871	Stability curves.
Retaining Walls	J. S. Tate	Engineer	XXXVI. 101	1873	Stability curves.
Erne Drainage Works	Anonymous	Engineering	XXXVIII. 272	1884	Forces on sluice.
Stability of Structures	F. A. Campbell	Engineer	LXII. 262	1886	Resistance curves.

RIVETED JOINTS.

Riveting (Ship-work)	M. Clauzel	Engineer	LI. 305	1881	Stress-strain (Inst. Mech. Engs.).
Riveted Joints	Prof. A. B. W. Kennedy	Engineer	LI. 325	1881	Stress strain (Inst. Mech. Engs., 1881).
Riveted Joints	Prof. A. B. Kennedy	Proc. Inst. Mech. Engs.	— 198	1885	—
Riveting Diagram	N. Foley	Industries	I. 36	1886	Single and double lap joints.
Diagonally Riveted Joints	J. T. Nicolson	Engineer	LXVI. 321	1888	Values of constants.
Diagonally Riveted Joints	J. T. Nicolson	Engineer	LXVI. 383	1888	Values of pitch.
Diagonally Riveted Joints	J. T. Nicolson	Engineer	LXVI. 445	1888	Values of constants.
Riveted Joints	Anonymous	Engineering	LII. 665	1891	Diagram for calculating the percentage of strength.

ROOFS.

Strains on a Timber-trussed Roof	Lieut.-Col. Waddington	Prof. Papers of Corps of Royal Engs.	X. 71	1849	—
Stability of Domes	E. W. Tarn	Proc. Roy. Soc. Lond.	XV. 183	1866-7	—
Theory of Reciprocal Figures	J. Clerk Maxwell	Engineer	XXIV. 402	1867	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXVII. 2	1869	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXVII. 122	1869	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXVII. 269	1869	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXVIII. 30	1869	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXVIII. 218	1869	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXIX. 46	1870	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXIX. 306	1870	Strains on roofs.
Construction of Roofs	Anonymous	Engineer	XXX. 451	1870	Strains on roofs.
Designing Pointed Roofs	T. Gillott	Engineer	XXXII. 88	1871	Strain diagram.
Construction of Roofs	Anonymous	Engineer	XXXII. 420	1871	Strain diagram.
Frames of Roofs	Prof. W. J. M. Rankine	Engineer	XXXIII. 114	1872	Strain diagram.
Strains in Iron Roofs	W. J. Millar	Engineer	XXXIII. 84	1872	Strain diagram.
New Town Hall, Reading	Max am Ende	Engineer	LII. 3	1881	Stresses.
Iron Roofs	A. T. Walmisley	Engineer	LII. 335	1881	Reciprocal diagram.
Snow Hill Station Roof	T. Timmins	Engineer	LIII. 23	1882	Reciprocal diagram
Swansea Station Roof	R. H. Graham	Engineer	LVI. 77	1883	Graphic treatment.
Framework	R. H. Graham	Engineer	LVI. 137	1883	Graphic treatment.
Framework	R. H. Graham	Engineer	LVI. 337	1883	Graphic treatment.
Graphic and Analytic Statics	A. Edmonds	Engineer	LVIII. 33	1884	Diagram of stress,
Huddersfield Station Roof	T. G. Gribble	Engineer	LX. 451	1885	Stresses.
Huddersfield Station Roof	R. E. Ellis	Engineer	LX. 475	1885	Stresses,

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		ROOFS—*continued.*			
Roof Principle, Calculation of Stresses	Max am Ende	Engineer	LXII. 399	1886	Diagrams.
Wind Pressure on Roofs	Prof. J. Thomson	Industries	III. 269	1887	Reciprocal diagram.
Carlisle Markets	Anonymous	Engineer	LXV. 305	1888	Curve of equilibrium.
A Rational Roof Truss	R. H. Graham	Engineer	LXIX. 393	1890	Stress diagram.
A Rational Roof Truss	J. Arajol	Engineer	LXX. 335	1890	Stress diagram.
New Market Hall, La Plata	Max am Ende, G. Scholes	Engineer	LXX. 430	1890	Force diagram.
		STRUTS.			
Struts	Profs. Ayrton and Perry	Engineer	LXII. 464	1886	Breaking weights.
Struts	Prof. R. H. Smith	Engineer	LXIV. 425	1887	Curves of coefficients.
		STRENGTH OF MATERIALS.			
Transverse Strain and Strength of Materials	E. Hodgkinson	Proc. Lit. Phil. Soc. Manch.	IV.	1824	—
Artificial Hydraulic Cement	G. F. White	Proc. Inst. C.E.	XI. 478	1851–2	Strength.
The Strength of Cement	J. Grant	Proc. Inst. C.E.	XXV. 66	1865–6	Diagram of comparative strength of cements.
Cast-iron Pipes	Anonymous	Engineering	III. 424	1867	Diagram of proportions of pipes.
Elasticity of Iron and Steel	Anonymous	Engineering	V. 48	1868	Stress strain diagram.
On an Uniform Wire Gauge	Latimer Clarke	Engineering	VI. 208	1868	—
Influence of Form on Strength	F. J. Bramwell	Rep. Brit. Assoc.	XXXIX. 422	1869	Strains.
Testing of Rails	J. Price	Proc. Inst. C.E.	XXXII. 192	1870–1	Stress strain diagrams.
Gearing for Yarn-winding Machinery	Anonymous	Engineering	XI. 20	1871	Diagram to find equidistant radii.
Steel Committee	D. Kirkaldy	Engineering	XI. 146	1871	Stress strain diagram.
Resistance of Armour Plates	Lieut. English	Prof. Papers of Corps of Roy. Engs.	XIX. 55	1871	Resistance at different velocities and thickness.

The Teeth of Wheels	T. Roberts	Engineering	XIV. 331	1872	—
Method of Drawing Wheel Teeth	T. Roberts	Engineer	XXXIV. 298	1872	—
On the Torsional Resistance of Materials	Professor R. H. Thurston	Engineering	XVI. 305	1873	—
Caution in the Use of Derrick Cranes	Anonymous	Engineering	XVI. 389	1873	Diagram of forces.
The Epicycloidal Wheel Teeth	Prof. W. C. Unwin	Engineering	XVII. 394	1874	—
Manufacture of Steel	W. Hackney	Proc. Inst. C.E.	XLII. 2	1874–5	Stress strain curve.
Strength and Fracture of Cast Iron	W. J. Millar	Trans. Inst. Engs. Shipbuilders Scot.	XIX.	1875–6	—
Strength and Fracture of Cast Iron	W. J. Millar	Engineering	XXI. 373	1876	—
Resistance of Materials	Professor R. H. Thurston	Engineering	XXII. 554	1876	Strain diagrams.
Strength of Unstaid Flat Surfaces	R. Wilson	Engineering	XXIV. 239	1877	Strain diagrams.
The Strength and Elasticity of Japanese Timber	G. Cawley	Engineering	XXIV. 387	1877	Strain diagrams.
Experiments on Japanese Wood	G. Cawley	Engineering	XXV. 248	1878	—
On some Formulæ for Pile-driving	A. C. Hurtzig	Engineering	XXVI. 141	1878	Diagram showing relation between energy of blow and driving power.
Steel Rails	C. B. Dudley	Engineering	XXVII. 185	1879	Diagram of chemical properties.
Strains on Crank Shafts	J. T. Milton	Engineering	XXVII. 349	1879	Diagram of twisting moment (Inst. Nav. Arch.).
Elasticity of Metals	J. T. Bottomley	Proc. Roy. Soc. Lond.	XXIX. 201	1879–80	—
On Certain Effects of Stress on Soft Iron Wires	J. A. Ewing	Proc. Roy. Soc. Lond.	XXX. 510	1879–80	—
Strength of Iron at High Temperatures	J. Kollmann	Proc. Inst. C.E.	LX. 417	1879–80	Stress strain diagram.
Strength of Iron at High Temperatures	Anonymous	Engineering	XXXI. 111	1881	Curve of time and temperature decrease.
Riveted Joints	Professor A. B. W. Kennedy	Engineering	XXXI. 436	1881	Stress strain diagrams (Inst. Mech. Eng.).
The Teeth of Wheels	Prof. MacCord	Engineering	XXXIII. 649	1882	Graphic construction.
The Teeth of Wheels	Prof. MacCord	Engineering	XXXIV. 51	1882	Graphic construction.
Strength of Steel Castings	Anonymous	Engineering	XXXIV. 401	1882	Transverse and torsional stress.
Shafts	J. Spencer & Sons	Engineer	LIV. 191	1882	Diagram of transverse stress.
Iron and Steel in Tension and Compression, &c.	P. V. Appleby	Proc. Inst. C.E.	LXXIV. 258	1882–3	Stress strain, &c.

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		STRENGTH OF MATERIALS—*continued.*			
Steel Castings *versus* Iron and Forgings	W. Parker	Journ. Iron and Steel Inst.	I.	1883	Deflection curve.
Testing Laboratory at Cooper's Hill	Anonymous	Engineer	LVIII. 70	1884	Stress strain diagrams.
Frequent Repetitions of Loads	Professor A. B. W. Kennedy	Occasional Papers of Corps of Roy. Engs.	X.	1884	—
Testing Portland Cement	J. L. Spoor	Engineering	XXXIX. 656	1885	Stress strain.
Testing Portland Cement	J. L. Spoor	Engineering	XL. 145	1885	Diagrams of strength.
Stress and Strain Diagrams	Prof. W. C. Unwin	Engineer	LIX. 408	1885	—
Strain Diagrams	Anonymous	Engineer	LIX. 419	1885	—
Autographic Strain Diagrams	Prof. W. C. Unwin	Engineer	LX. 158	1885	—
Rate of Hardening of Cement and Cement Mortars	Prof. W. C. Unwin	Proc. Inst. C.E.	LXXXIV. 399	1885–6	Curves of experiment and calculated values.
Liquid Fuel	Anonymous	Engineering	XLI. 609	1886	Table showing quantity of petroleum consumed by 8-wheeled locomotive.
Mild Steel	B. Martell	Engineer	LXI. 313	1886	Stress strain diagram (Inst. Nav. Arch.).
On the Strength of Iron and Steel in Shear and Torsion	J. Platt, R. F. Hayward	Proc. Inst. C.E.	XC. 382	1886–7	Tension diagrams.
Comparative Strength of Metals	Anonymous	Engineering	XLIV. 159	1887	Stress strain diagrams.
Aluminium Alloys	Anonymous	Engineer	LXIII. 28	1887	Stress strain curve.
Elastic Extension	R. H. Graham	Engineer	LXIV. 145	1887	Curves of acceleration and extension.
Elastic Extension	R. H. Graham	Engineer	LXIV. 185	1887	Curves of acceleration and extension.
Internal Stresses in Cast Iron and Steel	Gen. N. Kalakoutsky	Engineer	LXIV. 467	1887	Curves of stresses.
Strength of Copper Steam Pipes	N. Sinclair	Trans. Inst. Engs. Shipbuilders Scot.	XXXI.	1887–8	Diagram of experiments.
Manganese and its Application to Metallurgy	R. A. Hadfield	Proc. Inst. C.E.	XCIII. 1	1887–8	Stress strain diagram.

Emery Testing Machine	H. R. Towne	Proc. Inst. Mech. Engs.	— 206	1888	—
Manganese Steel	R. A. Hadfield	Engineering	XLVI. 228	1888	Stress strain diagrams.
Internal Stresses in Cast Iron and Steel	Gen. N. Kalakoutsky	Engineer	LXV. 41	1888	Internal stress in guns.
Internal Stresses in Cast Iron and Steel	Gen. N. Kalakoutsky	Engineer	LXV. 225	1888	Internal stress in guns.
Internal Stresses in Cast Iron and Steel	Gen. N. Kalakoutsky	Engineer	LXV. 298	1888	Internal stress in guns.
Bull's Patent Metal	Anonymous	Engineer	LXV. 420	1889	Stress strain diagram.
Thomasset Testing Machine	F. Gautier	Journ. Iron and Steel Inst.	I.	1888	—
Strength of Alloys at Different Temperatures	Prof. W. C. Unwin	Industries	VII. 526	1889	Tenacities (Brit. Assoc.).
Bull Metal	Anonymous	Engineering	XLVIII. 119	1889	Stress strain diagram.
Silica in Cast Iron	W. J. Keep	Engineering	XLVIII. 157	1889	Transverse strength.
Silica in Cast Iron	W. J. Keep	Engineering	XLVIII. 237	1889	Strength and shrinkage diagram.
Silica in Cast Iron	W. J. Keep	Engineering	XLVIII. 261	1889	Shrinkage, fluidity.
On Helical Toothed Spur and Bevel Whee's	E. Hunt	Engineering	XLVIII. 470	1889	Graphic method of construction.
Alloys of Iron and Silica	R. A. Hadfield	Engineering	XLVIII. 472	1889	Curves of strength and strain.
Alloys of Iron and Silica	R. A. Hadfield	Engineering	XLVIII. 503	1889	Stress strain diagram.
On Steel	C. H. Carus Wilson	Engineering	XLVIII. 700	1889	Stress strain diagram.
Aluminium Steel	R. A. Hadfield	Journ. Iron and Steel Inst.	IX. 417	1890	—
Changes in Iron produced by Thermal Treatment	E. J. Ball	Engineering	XLIX. 662	1890	Tensile strength (Iron and Steel Inst.).
Aluminium in Carburetted Iron	W. J. Keep	Engineering	XLIX. 767	1890	Transverse strength (Iron and Steel Inst.).
Measurement of Strains	A. Mallock	Engineering	L. 614	1890	Stress strain diagrams.
Irregular Wear of Locomotive Tyres	I. N. Barr	Industries	X. 219	1891	—
Strength of Copper and Various Alloys	T. H. Beare	Industries	X. 529	1891	Stress strain.
Rupture of Steel by Longitudinal Stress	C. A. Carus Wilson	Proc. Roy. Soc. Lond.	XLIX. 243	1891	Stress strain diagrams.
Young's Modulus for Crystals	A. Mallock	Proc. Roy. Soc. Lond.	XLIX. 381	1891	Stress strain diagrams.
Strength of Building Stones of Great Britain	T. H. Beare	Proc. Inst. C.E.	CVII. 341	1891–2	Crushing strength.
On Portland Cement	E. T. de Rochemont	Proc. Inst. C.E.	CVII. 377	1891–2	Stress strain.

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TIDES.					
Report on Tides	J. W. Lubbock	Rep. Brit. Assoc.	VII. 102	1837	Tidal curves.
River Orwell and Port Ipswich	G. Hurwood.	Proc. Inst. C.E.	XX. 4	1860	Tide gauge and diagrams.
On the North Sea	J. Murray	Proc Inst. C.E.	XX. 16	1861	Velocity of currents in feet per minute.
Tidal Observations—Rivers Humber and Trent	J. Oldham and Committee	Rep. Brit. Assoc.	XXXIV. 129	1864	—
Outfall of the River Humber	W. Shelford.	Proc. Inst. C.E.	XXVIII. 472	1868–9	Tidal curves.
Treatment of Sewage by Precipitation	W. Shelford.	Proc. Inst. C.E.	XLV. 144	1875	Tidal curves.
Tidal Portion of the River Mersey.	J. N. Shoolbred	Proc. Inst. C.E.	XLVI. 20	1875–6	Tidal curves.
The Hooghly Floating Bridge	B. Leslie	Proc. Inst. C.E.	LIII.	1877–8	Tidal curves.
Stationary Tides	Sir Wm. Thomson and others	Rep. Brit. Assoc.	XLIX. 70	1879	—
Tides in the Neighbourhood of Portsmouth	B. O. Townshend	Proc. Inst. C.E.	XCVII. 273	1888–9	Tidal curves.
VALVES AND VALVE GEARS.					
Allen's Valve and Valve Gear	Anonymous	Engineer	XIV. 336	1862	Valve diagrams and link motion.
Slide Valves in Marine Engines	N. P. Burgh.	Engineer	XX. 35	1865	Valve diagram.
Action of Engines	N. P. Burgh.	Engineer	XX. 67	1865	Indicator diagram.
Action of Engines	N. P. Burgh.	Engineer	XX. 164	1865	Valve diagram.
The Friction of Slide Valve and its Appendages	T. Adams	Trans. Soc. Engs.	— 6	1866	—
Walschaërt's Valve Gear	Anonymous	Engineering	II. 461	1866	Diagram of motion.
Friction of Slide Valves	T. Adams	Engineer	XXI. 113	1866	Forces of friction.
Theory and Practice of the Slide Valve	T. Adams.	Trans. Inst. Engs. Shipbuilders Scot.	X.	1866–7	—
Nature and Action of Safety Valves	T. Baldwin	Trans. Soc. Engs.	p. 23	1867	Pressure and discharge.
Variable Expansion Gear	E. S. Hindley	Engineer	XXIII. 258	1867	Indicator diagram.
Action of Safety Valves	T. Baldwin	Engineer	XXIII. 145	1867	Pressure curve.

Movable Seats for Slide Valves	J. R. Napier, W. J. M. Rankine	Engineer	XXIV. 336	1867	Valve diagrams.
Prof. Zeuner's Valve Diagram	Anonymous	Engineering	IV. 305	1867	—
Prof. Zeuner's Valve Diagram	Anonymous	Engineering	IV. 332	1867	—
Corliss Expansion Valve Gear	W. Inglis	Proc. Inst. Mech. Engs.	— 177	1868	Indicator diagram.
Allen's Engine	Anonymous	Engineering	V. 143	1868	Valves and valve gears.
Zeuner's Valve Diagram	E. Gieseler	Engineering	VI. 401	1868	Valve diagrams.
Double Slide Valve	W. Hartnell.	Engineering	VI. 506	1868	Valve diagrams.
Valve Gear of the Steamship 'London'	Anonymous	Engineer	XXV. 92	1868	Indicator diagram.
New Safety Valve	T. Adams	Trans. Inst. Engs. Scot.	XIII.	1869–70	—
Robey's Valve Gear	Robey and Co.	Engineer	XXIX. 34	1870	Indicator diagram.
Cut-off Slide Valve	W. Clapperton	Trans. Inst. Engs. Shipbuilders Scot.	XIV.	1870–1	—
Balanced Slide Valve for Locomotive Engine	W. G. Beattie	Trans. Inst. Mech. Engs.	— 35	1871	Indicator diagram.
Wilson and Pebble's Slide Valve	Wilson and Pebble	Engineering	XI. 304	1871	—
Guinotte's Expansion Gear	Anonymous	Engineering	XII. 228	1871	Valve-motion diagram.
Jenning's Patent Anti-back-pressure Valves	Anonymous	Engineer	XXXI. 161	1871	Valve diagrams.
Expansion Valves	Anonymous	Engineer	XXXI. 284	1871	Valve diagrams.
Locomotive Valve Gear	S. Hannah	Engineering	XIII. 132	1872	Valve and crank-effort diagrams.
Details of Valve Gear	Anonymous	Engineering	XIII. 138	1872	Steam curves.
Epicycloidal Valve Gear	W. Hartnell.	Engineering	XIII. 159	1872	—
Safety Valve Improvements	Anonymous	Engineering	XIV. 294	1872	Diagrams of pressure and lift.
Expansion Valves	T. Mannock	Engineering	XV. 209	1873–4	—
Correy's Variable Expansion Gear.	Anonymous	Engineering	XX. 354	1875	Indicator diagram.
Safety Valves	J. F. Flannery	Engineering	XXIII. 285	1877	Relative of lifts of ideal valve (Inst. Nav. Arch., 1877).
Automatic Expansion Gear	J. C. Fell	Engineering	XXIV. 99	1877	Indicator diagrams.
Correy's Expansion Gear	T. Powell	Trans. Inst. Mech. Engs.	— 504	1878	Indicator diagram.
Engine Trials	Anonymous	Engineering	XXV. 23	1878	Valve and indicator diagrams.
Collmann's Expansion Gear	A. Collmann	Engineering	XXV. 46	1878	Valve diagrams.
Valve Motion of a Horizontal Engine	M. A. Duvergier	Engineering	XXV. 429	1878	Distribution of steam curves.
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Subject	Author	Journal	Vol. and Page	Date	Kind of Curve
		VALVES AND VALVE GEARS—*continued.*			
14-Horse-power Engine at the Kilburn Show	Anonymous	Engineering	XXVIII. 5	1879	Valve diagram of steam admission.
Reversing and Expansive Valve Gear	D. Joy	Trans. Inst. Mech. Engs.	— 418	1880	Admission of steam.
Proell's Automatic Expansion Gear	Anonymous	Engineering	XXIX. 417	1880	Indicator diagram.
Marshall's Valve Gear	W. M. Angus	Engineering	XXXII. 460	1881	Valve and link-motion diagrams.
Parson's Expansion Gear	Anonymous	Engineering	XXXIV. 135	1882	Valve and indicator diagrams (Inst. Mech. Engs.).
Automatic Expansion Gear	W. Hartnell	Engineering	XXXIV. 204	1882	Indicator diagrams and pounds of water per 4 H.P. per hour (also Inst. Mech. Engs., 1882).
Stevenson and Price's Automatic Expansion Gear	Anonymous	Engineering	XXXV. 106	1883	Indicator diagrams.
Radial Valve Gears	R. H. Graham	Engineer	LV. 139	1883	Valve diagrams.
Radial Valve Gears	R. H. Graham	Engineer	LV. 252	1883	Valve diagrams.
Radial Valve Gears	R. H. Graham	Engineer	LV. 315	1883	Valve diagrams.
Radial Valve Gears	R. H. Graham	Engineer	LV. 499	1883	Valve diagrams.
Morton's Patent Valve Gear	Anonymous	Railway Engineer	IV.	1884	Diagrams and plate with motions of connecting rod.
Practical Results obtained from the Joy's Valve Gear	Anonymous	Railway Engineer	IV.	1884	—
English's Valve Gear	Anonymous	Engineering	XXXVII. 284	1884	Indicator and Zeuner's diagrams.
Wheelcock Automatic Expansion Gear	Anonymous	Iron	XXVI. 49	1885	—
Davey's Differential Valve Gear	Anonymous	Engineering	XL. 226	1885	Indicator diagram.
Fletcher and Man's Valve Gear	Anonymous	Engineer	LIX. 305	1885	Indicator diagrams.
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Proell's Automatic Expansion Gear	H. Kühne	Trans. Mining Inst. Engs. Scot.	VII.	1885–6	—
Wheeled-coupled Bogie Passenger Engine: Joy's Valve Gear	Anonymous	Railway Engineer	VII.	1886	—
Radial Valve Gears	L. Grunger	Engineering	XLI. 61	1886	Diagrams of link motions.

Procll's Automatic Expansion Gear	Anonymous . .	Engineering . . .	XLI. 250	1886	Indicator diagrams.
Peck's Slide Valve	Anonymous . .	Engineering . . .	XLII. 156	1886	Steam pressure and revolutions.
Radial Valve Gears	Anonymous . .	Engineering . . .	XLII. 279, 280, 360	1886	Valve motions.
Tangye and Johnson's Automatic Expansion Gears	Anonymous . .	Engineering . . .	XLII. 314	1886	Indicator diagram.
Modern Practice in Slide Valves .	T. Westgarth .	Engineer . . .	LXI. 112	1886	Indicator diagram.
Finding the Point of Cut-off and Lap	V. Thallmayer .	Engineering . . .	XLIV. 586	1887	—
Slide-valve Diagrams . . .	T. B. Mackenzie .	Engineering . . .	XLIV. 687	1887	—
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Slide-valve Diagrams . . .	V. Thallmayer .	Engineering . . .	XLVI. 180	1888	—
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The Joy Valve Gear . . .	D. Joy . . .	Trans. Inst. Engs. Shipbuilders Scot.	XXXII.	1888–9	Indicator diagram.
Friction of Locomotive Slide Valves	J. A. F. Aspinall .	Proc. Inst. C.E. . .	XCV.	1888–9	Slide valve diagram.
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Oscillation of Railway Carriages	Anonymous	Railway Engineer	V.	1884	—
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On an Improved Form of Seismoscope	Prof. A. Herschel	Trans. N. Eng. Inst. Mining and Mech. Engs.	XXXVII.	1887–8	Lines of force.
On the Balancing of Marine Engines and the Vibrations of Vessels	A. F. Yarrow	Marine Engineer	IV. 158	1892	Vibrometer.
		GENERAL.			
On the Relative Value of the Furnace and Steam Jet in the Ventilation of Coal Mines	N. Wood	Trans. N. Eng. Inst. Mining and Mech. Engs.	I.	1852–3	Diagrams.
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Straining Effect of a Sudden Load	Prof. W. J. M. Rankine	Engineer	XV. 121	1863	Stress strain diagram.
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Mechanical Power in Colliery Operations	E. Bainbridge	Trans. Chesterfield and Midland Inst. Engs.	III.	1875	Diagrams of labour cost, &c.
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Horizontal Pans for Feeding Furnaces	J. J. Butcher	Engineering	XXV. 178	1878	Diagram of distribution of coal on grate.
Coal Winding in Deep Shafts	A. H. Stokes	Trans. Chesterfield and Midland Inst. Engs.	VI.	1878	Indicator diagram of winding engines.
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Gas Holders at the South Metropolitan Gas Works	Anonymous	Engineering	XXXII. 506	1881	Diagram of bursting pressure and discharging force.
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Blast Furnace Working	C. Cochrane	Engineer	LIV. 116	1882	Coke consumed.
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Transmission of Power by Gearing	W. Lewis	Engineering	XL. 607	1885	Efficiency of apparatus and speed of worm.
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Combustion with Natural and Forced Draught	W. G. Spence	Engineering	XLV. 225	1888	Temperature.
Chronometer Rates, and How to Use them at Sea	Anonymous	Engineering	XLVI. 623	1888	Curve of error.

Shield Tunnelling in Loose Ground under Water Pressure, with special reference to the Vyrnwy Aqueduct Tunnel under the Mersey. By GEORGE F. DEACON, *M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

IT is impossible, within the limits of a British Association paper, to give anything like an historical account of the tunnel which has recently been successfully completed under the river Mersey for connecting the Lancashire and Cheshire portions of the Vyrnwy Aqueduct. A romantic and instructive account might well be written of the battles with the elements, of the repeated failures and successes, and of the hairbreadth escapes, with ultimate pronounced success, which attended this subterranean and subaqueous work.

From first to last the operations, including stoppages, occupied forty-seven months. At the end of twenty months the first contractors had completed the work of driving and lining the tunnel from the Cheshire shaft to a distance of 57 feet out of a total of 805 feet required, when, having also sunk the greater part of the Lancashire shaft, they ceased work. The second contractors, rather than reopen the disturbed ground of the old workings, began, with permission, at a higher level on the Lancashire side. At the end of a further period of twenty-one months they had driven and lined 182 feet from the Lancashire shaft. They then relinquished the work, and it was taken up by the Corporation of Liverpool, most of the men being retained and one of the contractors continuing to superintend them. After this the remaining length, about 620 feet, was driven and lined in four and a half months, the maximum progress being 57 feet per week of 110 hours.

In the case of the first Thames Tunnel the practical difficulty of carrying on the operations successfully, either by contract or piecework, impressed itself upon the mind of the elder Brunel. It was, indeed, the only evil against which, with marvellous foresight and ingenuity, he could not make provision. The same sort of difficulty has very forcibly shown itself in this case, and there appears to be no doubt that if the work had been taken up in the first instance on the basis ultimately adopted, the whole of it would have been as successfully and economically performed as the last length of 623 feet, which was carried out, without the intervention of a contractor, in four and a half months.

The general particulars of the Vyrnwy Aqueduct Tunnel are as follows :—

	Ft.	In.
LANCASHIRE SHAFT—		
Depth	59	0
Outside diameter	10	9
Inside diameter	9	9
At junction with tunnel, outside diameter	13	9
„ „ inside „	12	9
CHESHIRE SHAFT—		
Depth	52	6
Outside diameter	10	9
Inside diameter	9	9
At junction with tunnel, outside diameter	15	0
„ „ inside „	14	0

TUNNEL—	Ft.	In.
Length, about	800	0
Outside diameter	10	0
Inside diameter	9	0
Low-water level above invert—		
Lancashire end	37	0
Cheshire end	31	0
High-water spring-tide level above invert—		
Lancashire end	54	0
Cheshire end	48	0

The shafts are lined with cast-iron cylinders, the tunnel with cast-iron segments bolted together and planed on the abutting edges.

The peculiar difficulties of this work arose from the fact that, while the whole of the material (except certain small lenticular masses of clay) through and beneath which the tunnel was driven was perfectly loose and full of water under direct pressure from above, it constantly varied in the size of its component parts from the finest mud to the coarsest shingle, containing comparatively little sand. In homogeneous mud the operations would have been comparatively easy, but the face of the excavation was quite commonly composed of three totally different materials, such as open shingle, sand, and mud, all three under the full and varying pressure of the tidal water above, and all three behaving in a totally different manner; while in some cases a band of hard clay was met with, impervious in itself, but surrounded by water under pressure, never covering the whole face, but sometimes in the bottom, sometimes in the middle, and sometimes in the top.

The following considerations will make the great difficulty thus presented more obvious. In sinking a shaft under air pressure we free the ground by excavation within and beneath the circular cutting edge attached to the lowest cylinder. That edge being horizontal, we are generally able to maintain the air within the vertical cylinders at such a pressure that the water is kept back at every point of the cutting edge. The cylinders, then, owing to their own or to a superimposed weight, sink farther. They are from time to time lengthened by adding cylinders at the top; and by freeing the ground below the cutting edge this lining is sunk to the required depth.

In 1825 Brunel began the use of the first iron tunnelling shield. By this marvellous adaptation of means to ends—of mechanical methods to meet every physical difficulty that great personal experience of tunnelling could suggest—we find an advance in the science of tunnelling which, having regard to the materials then available, was greater than any advance since made. The shield was, like the brickwork forming the twin tunnels, rectangular. It supported the ground in front. It supported the ground overhead, not only by an inverted slipper travelling with the shield, but by an extension backward, consisting of a wrought-iron plate attached to the slipper and resting upon the top of the finished brickwork, over which it was drawn as the shield advanced. For the rest, the shield was divided vertically into twelve vertical frames, each capable of being advanced alternately or in any other order; and each of these vertical frames supported against the face of the excavation forty-four timber shields, each as long as the frame was wide—viz., 3 feet—and 6 inches deep; and each of these minor shields could be removed or advanced separately.

Next came Mr. Peter Barlow, who more nearly imitated, in horizontal driving, the sinking of a cast-iron cylinder. He acknowledged his indebtedness to Brunel, the great originator of shield tunnelling. He substituted cast iron for brickwork, made his tunnel circular, and surrounded his circular shield by a cylinder which overlapped the tunnel, not merely at the top, but all round. For the screws used by Brunel to propel his great frames and minor shields Mr. Barlow substituted hydraulic rams, and he pushed the shield forward in stages to a sufficient extent to enable him to add ring by ring to the forward end of the tunnel lining.

This device was explained by Mr. Barlow in a pamphlet published in 1867, 'On the Relief of London Street Traffic, with a Description of the Tower Subway, now shortly to be executed.' According to his method, he carried out with complete success the Tower Subway, eight feet in diameter, beneath the Thames. Since that time Mr. Greathead has introduced many ingenious improvements and additions.

In applying this method directly loose materials under water pressure are met with the much greater difficulty of driving horizontally than of sinking vertically is experienced. If artificial air pressure is employed—and in many cases it has not yet been found practicable to dispense with it—new difficulties arise.

The conditions of equilibrium between the air pressure within the tunnel and the water pressure without the tunnel are obviously different at different levels of the face. Such equilibrium as permits the work to be continued is difficult to attain, and when attained is highly unstable. To meet this difficulty Mr. Greathead has devised many ingenious arrangements, in one of which he excavates by means of hydraulic jets in front of the closed shield or diaphragm (still surrounded by the annular shield overlapping the finished work), and removes the fluid ground by a pipe passing through the shield to the tunnel.

But the great variety of material met with in the Mersey Aqueduct Tunnel, including large shingle and in many cases heavy oak timber in good condition, lying prostrate across or parallel with the axis of the tunnel, rendered the use of any such methods impracticable.

In order to understand rightly the nature of the problem, regard must be had to the following considerations:—

Imagine a face with loose material at the end of the finished portion of the tunnel subject to the pressure, let us say, of 30 feet of water to the top, and of 40 feet of water to the bottom of the tunnel, the tunnel being charged with air to balance, let us suppose, the 40 feet. One of two things immediately takes place. Either the air pressure, overbalancing the water pressure where at the higher part of the face it has only a head of 30 feet, rushes out in such quantity as to form an upward funnel through the strata, in which case water rushes in below where the pressure in front of the shield is 40 feet; or the air simply displaces the water in the interstices of the porous ground. This latter action is also very rapid. The wet surface of the face seems instantly to dry up; in fact, so complete and rapid is the drying that in a few seconds it is difficult to imagine that the face has been wet within the last twenty-four hours. But with this change the whole condition of equilibrium is altered. The head of water at the face is partly displaced by a head of air—a great bubble—in the interstices of the ground, having the form of a balloon, continuously supplied with air, from the end of the tunnel, which it dissipates from its

upper surface into countless smaller bubbles, so that the total pressure at the face is suddenly much diminished. The flow of air through the interstices of the material continues, and only attains a normal rate—equal to the supply of air to the tunnel—when the pressure in the tunnel has so far fallen as to exactly balance the static head of air and water above the face, plus the friction of the moving air in the interstices of the ground. This state of things lasts, and the ground continues to be held back in a visibly dry condition, until, by a change of resistance to the passage of the air upwards through the ground, the equilibrium is again disturbed. With every rise or fall of the tide such a change occurs, and in the case of the Vyrnwy Aqueduct Tunnel under the Mersey it took place in virtue of a change of the strata at every few yards driven. In a vertical shaft such changes are comparatively unimportant, but in a horizontal tunnel the case is clearly very different.

Even in ground of uniform porosity it is generally difficult to keep the water back at the lower edge of the shield, and obviously this must be so, because at this point the water when quiescent has nearly the full hydrostatic head, notwithstanding the great bubble of air moving in the interstices above it. It is therefore generally necessary to permit a small inflow of water to take place at this point, and thus to allow the friction of the water through the ground to bring the pressure in the ground at the bottom of the shield down to the lower pressure in the tunnel required to balance the pressure higher up the face; but, if the flow at this lower point is allowed to become sufficient to disturb the ground, the resistance to that flow is reduced, the equilibrium is upset, the great bubble is displaced and lifted by the moving sand and water below, and an inrush instantly occurs.

So much for strata of uniform porosity. But, as already stated, the Vyrnwy Aqueduct Tunnel had to be driven through rapidly varying strata. From time to time, without any warning, the resistance to the inward passage of water at the lower edge of the shield suddenly fell. Almost instantly the great bubble of air was lifted bodily, and the face of dry ground became a surging current of liquid mud. Occasionally the same change began at a higher level of the face, owing to the resistance of a higher stratum to the passage of water rapidly falling. But however it arose, the result was an instant upsetting of the equilibrium, and a dangerous rush of liquid ground into the tunnel.

The shield employed by the second contractor for driving the Vyrnwy Aqueduct Tunnel was of the Barlow form—a cylinder with its forward end carrying a cutting edge, and its backward end overlapping the finished work all round, and a diaphragm across it provided with many covered openings, through which the excavation was performed. But the construction of the shield was much too light, and when the work was taken over by the Corporation, the cutting edge had collapsed and bent inwards for about one-fourth of the circumference to an extent in one place of about 15 inches. Moreover, there was a longitudinal crack near the bottom of the annular shield, extending from the tail nearly to the diaphragm.

As usual in such cases, it was at this stage commonly asserted that the work was impracticable, and would never be finished. It had most seriously delayed the completion of the Vyrnwy Aqueduct; but even at this late period the necessity for obtaining an Act of Parliament to deviate the line of aqueduct was in some quarters seriously contemplated.

Familiarity with the subaqueous workings had, however, only served to confirm the author's opinion of the feasibility of the undertaking, which at an earlier stage he had offered to carry out without the intervention of a contractor, and this course was now decided upon.

To have to conduct the work with a shield insufficiently strong and in such a condition was not a satisfactory beginning. The author had no doubt whatever that with a properly designed shield it could have been rapidly performed. He was not certain that it could be done with the existing shield, but all things considered, and rather than attempt to replace it in the disturbed ground in which it then lay, it was thought better to repair and strengthen the existing shield, and at least to make an effort to proceed with it. The repairing and strengthening of the cutting edge was successfully performed, and 42½ months after the commencement of the first contractor's work the tunnel was recommenced. The most effective method was found to be to remove the lower part of the diaphragm, as shown in the model exhibited, to regulate the air pressure as nicely as possible at such a point below the hydrostatic pressure that, while—so long as the shield was kept moving—it was generally insufficient to blow a funnel from the upper edge of the shield to the river above, it was just sufficient to prevent an inflow at the lower edge of the shield sufficiently rapid to carry the ground with it.

At intervals round the cutting edge steel teeth were added before the work was recommenced, and the author is disposed to think that they were of great use in penetrating shingle. Several feet behind the main diaphragm was placed a partition projecting upwards to a level above that of the underside of the remaining portion of the main diaphragm. This proved to be exceedingly useful when a blow of sand and water occurred. It did not materially hinder access to or from the front of the shield, while there can be no doubt that when a blow took place it choked itself more readily than if such an obstruction had not existed. The author was indebted to Sir Benjamin Baker for suggesting this device, and that of the teeth.

During the latter part of the progress the longitudinal crack already mentioned near the bottom of the shield became worse, another crack worked from it circumferentially behind the diaphragm, and the plates of that portion turned down like a ploughshare from their proper position. This caused a delay of twelve days, included in the 4½ months. The ground at the time was as bad as it could be, but the piece, 6½ feet long and 9 feet wide, was successfully cut away and replaced *in situ*. The portion cut away could not be removed, but was left behind by the advancing shield when the work was recommenced.

In judging of this work it is not to be supposed that it was undertaken in a foolhardy manner. Such an operation was never contemplated when the parliamentary plans were deposited, but, on the contrary, the aqueduct pipes were shown by those plans to be laid in the bed of the river, and the softest bed was chosen for the purpose—the very worst place, in fact, for the construction of a tunnel. For reasons which it is not necessary to recount, the question of the depth at which the aqueduct should be laid was referred to the Board of Trade. The Board would probably have been more merciful if it had foreseen, as the advisers of the Corporation of Liverpool foresaw, the pending difficulties; but, as a matter of fact, the decision required the aqueduct to be laid at such a

depth that tunnelling became a necessity. The necessity having arisen, it was not shirked, and the work has been successfully accomplished.

In conclusion, the author desires to draw attention to the fact that the condition of unstable equilibrium to which he refers, and which creates most of the difficulties in shield and pneumatic tunnelling, rapidly increases with the diameter of the tunnel. He has no doubt whatever that a shield may be constructed in any particular case to meet all the contingencies that can arise; but it is from works like the Vyrnwy Aqueduct Tunnel under the Mersey, in which the means of meeting difficulties are not sufficiently provided, and where success is nevertheless attained, that the most valuable lessons are to be learnt.

Report of the Committee, consisting of Sir W. H. Flower (*Chairman*), Dr. J. G. Garson (*Secretary*), Dr. J. Beddoe, General A. H. L. Pitt-Rivers, Mr. Francis Galton, Dr. E. B. Tylor, *and* Mr. E. W. Brabrook, *appointed for the purpose of editing a new Edition of 'Anthropological Notes and Queries.'*

The Committee have to report that, in accordance with previous Reports, the Anthropological Institute of Great Britain and Ireland has now completed the task entrusted to it of editing and publishing a second edition, consisting of 500 copies, of 'Notes and Queries on Anthropology,' at a cost of 86*l.*, which includes the cost of partially stereotyping the work for use in a future edition. This expenditure has been met as follows:—Grants from the British Association, 70*l.*; donation by the late Dr. Muirhead, of Glasgow, 10*l.*; and the balance by members of the Committee.

The work as published consists of 242 pages, as against 146 pages in the previous edition; a double-coloured plate and three other new plates have been specially prepared for this edition, and the illustrations of the former edition have been again used as far as the editors have thought it desirable. All the sections have been thoroughly revised, several of them have been rewritten, others which were left blank in the first edition have been filled up in this, and several new sections have been added.

As the Committee considered that the object for which the work is published is to enlist the co-operation of as many workers as possible, as well as to guide and direct them in their observations, the Committee have arranged with the Council of the Anthropological Institute that, notwithstanding its increased size and cost of production, the publishing price of the new edition shall be the same as that of the first edition, namely 5*s.*, and that a discount of 1*s.* 6*d.* shall be allowed to members of the British Association and Anthropological Institute, making the nett price of the work 3*s.* 6*d.* for cash, at the office of the Anthropological Institute, 3 Hanover Square, London, W.

The Committee consider it very important for the advancement of anthropological science that means should be taken to bring the work under the notice of travellers and others who are willing to undertake anthropological research, and in some cases to make direct application to persons in a position to collect information on various subjects included in the scope of the work. To do this the Council of the Anthropological Institute possess far greater facilities than any committee of the British

Association. The Committee therefore recommend that this duty be delegated to the Institute, which, they have ascertained, is willing to undertake it for the Association; and they further recommend that the Institute be entrusted with the distribution of this second edition by gift and by sale in the way it may consider most conducive to the objects for which the work was designed, on the understanding that the sum realised from sales be kept by the Anthropological Institute in a separate account towards defraying the cost of hereafter preparing and publishing a third edition of the work when necessary. The Committee have, in the meantime, placed 150 copies at the disposal of the Institute for this purpose, for review, and for presentation to the editors and the authors of Sections, whose labours have been entirely gratuitous. The Anthropological Institute has undertaken to advertise the book gratuitously in its journal.

Report of the Committee, consisting of Dr. J. G. Garson (*Chairman*), Mr. J. Theodore Bent (*Secretary*), *the late* Mr. H. W. Bates, Mr. G. W. Bloxam, Mr. J. Stuart Glennie, Sir Frederic Goldsmid, Mr. W. Pengelly, *and* Mr. F. W. Rudler, *for investigating the ruins of Mashonaland and the habits and customs of the inhabitants.* (*Drawn up by* Mr. J. Theodore Bent.)

The Committee have to report that during the past year a large amount of information has been collected by Mr. and Mrs. Bent during their travels in Mashonaland, and submit the following account of their journey, by Mr. Bent, as their report.

Report to the Committee on Investigations in Mashonaland.
By Mr. J. Theodore Bent, *Secretary of the Committee.*

The principal feature of our work in Mashonaland consisted in studying, making measurements and plans, and excavating in the ruins called Zimbabwe in Mashonaland. For three months after this work was over we travelled through the country, visiting the native kraals and collecting a large mass of anthropology from the habits and customs we saw around us. In the following report I shall deal more at length on the subject of the ruins, as they formed the main object of our work.

The ruins of the Great Zimbabwe, which name I have given to distinguish them from the numerous minor Zimbabwes scattered over the country, are situated in south latitude 20° 16′ 30″ and east longitude 31° 10′ 10″, at an elevation of 3,300 feet above the sea-level, and form the capital of a long series of such ruins stretching up the whole length of the west side of the Sabæ River, the southernmost which we visited being that on the Lundi and the northernmost in the Mazoe Valley; there are also many other ruins on the Limpopo, in the Transvaal, in Matabeleland, at Tati, the Impakwe and elsewhere, all of the same type and construction, which time would not permit of our visiting. Some are equal to the ruins of Great Zimbabwe in workmanship; others, again, are very inferior, and point to the construction and occupation of this country having continued over a long period, probably centuries; and then all would seem to have been abandoned at one time in the face of some overwhelming calamity, for all the gateways at the Great Zimbabwe and at

Matindela, the second ruin in importance, eighty miles north-east of it as the crow flies, have been carefully walled up as for a siege, and a forcible entry had been effected into the Great Zimbabwe by a gap in the weakest part of the large circular building. Doubtless at this capture of the fortresses a wholesale massacre of the inhabitants took place, and a complete destruction of the people and their objects of art.

The Great Zimbabwe ruins cover a vast area of ground, and consist of the large circular building on a gentle rise, with a network of inferior buildings extending into the valley below, and the labyrinthine fortress on the hill, about 400 feet above, naturally protected by huge granite boulders and a precipice running round a considerable portion of it. From the plan and model exhibited a fair idea of the lower building can be obtained. It is built of small blocks of granite broken with the hammer into a uniform size, but bearing no trace of chisel-marks whatsoever, and no mortar had been used in the construction. In parts this encircling wall is 30 feet high and between 16 and 17 feet in thickness, and the courses of small stones are carried out with surprising regularity, arguing an excessive amount of labour, at a time when slave labour was abundant and time no object, and an accurate knowledge of levelling.

There are three entrances on the north side of the circle, carefully rounded off and protected on the inside with buttresses: that to the north, facing the fortress on the hill, would appear to have been the principal one, the small space inside being floored by strong reddish cement. Five passages led away from this entrance amongst the labyrinthine buildings inside: the one to the left went down some cement steps, and was carefully protected by a doorway consisting of two buttresses with apertures on either side to receive some form of door, which seems to have been universally employed in the buildings, but which at the time of the siege had been removed and their places supplied by walls carefully constructed of the same kind of stones as the outer walls; then it led into the long narrow passage which conducted between high walls to the sacred enclosure.

When we got to the Great Zimbabwe all the entrances were closed up. By climbing over fallen débris we reached the interior, only to find ourselves impeded by a maze of thick tropical vegetation which entirely concealed the ground plan of the building, and which took us some days to clear away.

The above-mentioned long mysterious passage led, as I have said, to the sacred enclosure, where stand the two towers; the largest is now 32 feet high, with a girth of 53 feet 10 inches, and had presumably a few more courses; a few courses below the summit ran a pattern formed by the stones in one course being placed edgeways. This tower is really a wonderful structure, of perfect symmetry, and with courses of unvarying regularity. By working underneath it and by extracting as many stones as we dared from two holes in the side, which we afterwards replaced, we satisfactorily demonstrated that it was solid; it was built on no other foundation but the hard clay of the place, and covered nothing, and the foundations only go down about two feet below the present level and a foot below a floor of cement which presumably covered this enclosure. It has been preserved to us simply by its solidity and the way in which the stones have supported one another. Its religious purport would seem to be conclusively proved by the numerous finds we made in other parts of the ruins of a kindred nature.

There are several points of interest connected with this sacred enclosure. The inner wall in front of the tower had been decorated with courses of black slate; a curious conduit about a foot square and regularly constructed runs right through the thickness of the outer wall at its thickest point. Similar and equally inexplicable conduits we found about the temple on the fortress. Then there is the raised platform, approached by cement steps and a gateway just in front of the tower, covered itself with a thick cement, into which a monolith had been stuck; this platform must have been for the king or officiating priest. The whole of the sacred enclosure had been most carefully protected by gates and buttresses: it is sunk a little lower than the rest of the building, and the outer wall is here at its strongest and thickest, and is, moreover, decorated on the outside with the pattern which stops abruptly at the place corresponding with the termination of the sacred enclosure in the interior, and the summit of the wall for this portion only had been decorated with large monoliths.

The rest of the enclosure would appear to have been occupied by private buildings also enclosed with circular walls, according, as Doughty tells, to the ancient Arabian custom of combining their temples and fortifications in one; and El Masoudi also tells us that most of the Sabæan temples were round.

The monoliths form a marked feature: two over 13 feet in height stand near the north-western entrance; a third lay prostrate a few yards away. The summit of the walls, too, was interesting; it had been approached by steps from the principal entrance, was originally paved, and hence formed a fine broad promenade with that curious decoration of monoliths along it.

Externally the walls are very fine, and the courses, from their extreme evenness, give the building a neat and compact appearance. The pattern which only decorates the part outside the long passage and the sacred enclosure is in two rows let into the wall and formed by stones placed in a chevron pattern, and must have required considerable skill to execute as the building was proceeding. The circle of the walls is by no means true, and the nature of the building is different; as I have already mentioned, the portion from the main entrance and round the sacred enclosure is higher, thicker, and more carefully built; the rest was either constructed at a later period or in a more careless manner; it is impossible now to walk on this portion of it, and it is rapidly falling into ruins. The middle entrance was evidently only a hole in the walls, or sally port, probably of later construction, with wooden beams supporting the superincumbent structure, and which have entirely given way.

Our excavations in this circular building were not attended with success. It bore traces of Kaffir habitation up to within a recent date, and they had evidently cleared out all traces of an earlier occupation; in some kitchen middens outside we came across traces of minor importance.

The principal part of our work and our most interesting discoveries took place on the hill fortress, to which we will now proceed, and the labyrinthine nature of which can be best realised by a plan made by Mr. R. W. Swan, and published for me by the Royal Geographical Society. The *kopje* itself is of great natural strength, being protected on one side by gigantic granite boulders, and on the south by a precipice from 70 to 90 feet in height, and on the only accessible side the inhabitants constructed a wall of massive thickness like those of the ruins below:

it is 13 feet thick on the summit, with a batter of one foot in six; it is 30 feet high in parts, and the flat causeway on the top was decorated on the outside edge by a succession of small round towers—seven in all we made out—about 3 feet in diameter, alternating with tall monoliths; a most peculiar and unique form of decoration.

To open out the approach to this fortress town was a work of considerable time and labour. It is exceedingly intricate, protected at every turn with traverses and ambuscades, and then commences at the bottom of the precipice a flight of steps, leading up. The architects have availed themselves of a narrow slit in the granite boulder, up which the steps led, the passage being exceedingly narrow; then the path divided into two, one path turning abruptly to the right, and at the turning a pretty little bit of wall with the stones placed pointways for about a yard relieved the monotony; then it led along a narrow ledge over the precipice, and in spite of the impossibility of attack at such a point it is nevertheless protected by traverses even here; in fact, the redundancy of fortification all over this mountain, the useless repetition of walls over a precipice itself inaccessible, the care with which every hole in the boulders through which an arrow could pass is closed, prove that the occupants were in constant dread of attack, and lived like a garrison in the heart of an enemy's country.

At the summit of the mountain are huge boulders about 50 feet high; immediately below the highest is a curious little plateau which had been decorated by the ancient occupiers: it is approached by narrow passages and steps on either side and a curious passage through the wall below covered with huge beams of granite to support the superincumbent weight. The steps on one side were made of the same strong cement, and the wall to the left was decorated with the same design of stones placed edgeways for six rows that we had at the angle of the approach. The little plateau itself was adorned with huge monoliths and decorated beams of soapstone, the patterns on which were chiefly of a geometric character, and one of which was 13 feet in height. Here, too, we unearthed many crushing stones of diorite and a curious stone with lines carried round it with great regularity; we found another similar one in the temple itself.

The large semicircular space below this was a dense jungle when we started to work, consisting of nettles of extraordinary pricking powers and other obnoxious plants which our natives cleared away; but here, again, were evident signs of fairly recent Kaffir habitation, beneath which further relics may be found, but our time and resources would not permit us to conclude this work. However, Mr. Cecil Rhodes has kindly consented to have the work carried on, so there is every hope of further material coming to hand. The view from this spot is magnificent over the Livouri and Bessa Mountains, and situated as it is far above the level of the marshy ground it would be healthy and habitable during all seasons of the year.

Time will not now permit me to enter into details concerning all the intricacies of this fortress; its narrow gullies protected for no conceivable reason with walls and traverses; its huge granite boulders with every slit through which an arrow could pass carefully walled up; but a glance at the plan will show its chief points better than any description by words can give.

The corner of the fortress which yielded our principal finds is now

used as a cattle kraal by the petty chief on the hill. This building was anciently the temple of the fortress, and was luckily not so much disturbed as the one below. The aspect was the same, namely, south-east, and the outer decoration, the pointed or edgeways pattern, ran around the same portion of the building as on the round one below. This temple among the granite boulders was supported by a very elaborately constructed system of under-walls filled up with large stones, on which the cement floor rested, as was the case in the raised platform below. The temple was approached by a narrow passage and a staircase of considerable architectural merit, which we laid bare; the steps are formed by a continuation of the rounded courses of the outer walls, and have the effect of two miniature amphitheatres opposite to each other which acted as steps from the passage below to the level of the temple itself.

The outer wall of this temple was decorated with birds carved on the summit of soapstone beams five or six feet in height. Of the six we have all are different, and all archaic in design; only one is perfect, and from its beak we can easily see that it is intended to represent a vulture. Two have decorations down the back and round the neck, and one has four circles cut on it, two on the wings and two below, presumably to represent incubation and fertility. Egyptian archæology teaches us something of the attributes anciently supposed to pertain to the vulture. Amongst other things Horapollo tells us (i., ii.) that it was emblematic 'of Urania, a year, or mother.' Ælian goes so far as to suppose that all vultures were females, to account for their character as emblems of maternity. This is a curious confirmation of the statement of Herodotus, that the Arabians only worshipped Dionysus and Urania. We have seen how the attributes of Dionysus were worshipped in the tower below; here we have Urania as the presiding deity. In the soil of the temple we found numerous soapstone objects corresponding to the Lingams of India, and a tiny bird on a pedestal, the miniature representative of the larger emblems.

An altar stood in the centre of the temple on the cement floor, which unfortunately fell to pieces after the earth which supported it had been a short time removed. Supporting walls gradually led up in steps to the boulders, and of two gullies between these boulders at the back of the temple one led to another enclosure with two huge monoliths in the centre, and a terrace above overlooking the temple, and the other led through into the native kraal on the other side of the wall of rock.

Adjoining the temple, and approached by a flight of steps, was a space shut in by boulders, and walled in with great care at the extremities. Two caves ran beneath the boulders, and in these we found most of our treasures.

Of these the most attractive are the numerous fragments of soapstone bowls, perhaps used in temple service and when broken cast out hither. One represents a hunting scene, in which a man, rather of a Hottentot type, with an arrow, is in pursuit of a herd of zebras; behind him he drags a dog with a leash, which has turned round to growl at two hippopotami. There is a bird, too, rather rudely executed, but this is the character of all the bowls with figures on them. The workmanship of the bowls themselves is excellent, and made with the chisel; geometric patterns also are executed with great care, but the figures are rather grotesque. Another bowl gives us a portion of a procession; another is decorated with a row of bulls. Different animals and different patterns were found on all the fragments, no two fragments of the same bowl ever occurring. Several of the best finished bowls were perfectly plain, notably one

very large one, which is almost intact, and has a very finely chiselled surface and well-rounded edges. There is one fragment on which I take it some letters are rudely scratched, resembling somewhat the Ogham characters or strokes on either side of a line to give them value. I have not yet found anyone who can suggest any solution of this problem, and I should have felt inclined to consider it hopeless had not Mr. Anderson shown me a sketch of a stone from Bechuanaland, taken thirty years ago, which has characters on it closely corresponding to these.

Many fragments of pottery of excellent glaze and workmanship were also found; the patterns on these are mostly geometric, but executed with absolute correctness with a stamp, and there appear to be wheel-marks at the back. Of the numerous implements of war we found many are doubtless Kaffir and of a later date. One, however, is an assegai with a heavy plating of gold on it, which must belong to an earlier period, and the spear-head of copper, heavily barbed, corresponds to weapons now found amongst natives not at a great distance from this spot. The iron bells, too, which we found in the ruins occur now on the Congo, hundreds of miles away; but the uniformity of design all over Africa and the conservative nature of these designs make it difficult to attach any date to them. Everywhere in the ruins we turned up circular whorls of pottery, some decorated and some plain, which at first we took to belong to spindles for cotton, but some are too small and could never have been used for that purpose. The circular soapstone object with knobs thereon, which was brought, together with the bird shown to the Section, by a Dutchman from Zimbabwe two years ago, Mr. Trimen, of the Cape Museum, has kindly lent for exhibition in England. The first impression it gives is that of a quern, but soft stone like this can never have been used for the purposes of grinding, and all objects of soapstone found in the ruins would appear to be for decorative purposes only.

In one corner of this same part of the fortress, near the surface, we found several fragments of Persian and Celadon china, doubtless used as barter goods by the Arab traders who came up from the coast; but nowhere during all our excavations could we come across any signs of coins or traces of a cemetery for the burial of the dead.

Perhaps the most interesting of our finds in this portion of the ruins were those in connection with the manufacture of gold. Close underneath the temple stood a gold-smelting furnace, made of very hard cement, with a chimney of the same material, and very neatly bevelled edges, portions of which are now on their way home. Hard by, in a chasm between two boulders, lay all the rejected quartz casings from which the gold-bearing quartz had been extracted by exposing them to heat prior to the crushing, proving beyond a doubt that these ruins, though themselves far removed from any gold reef, were the capital of a gold-producing people, who had chosen this hill fortress with its granite boulders owing to its peculiar advantages for strategic purposes.

Near the furnace, too, we found many little crucibles of a composition of clay, which had been used for smelting the gold, and in nearly all of them exist small specks of gold adhering to the glaze formed by the heat of the process. There are tools also amongst our finds for extracting gold, burnishers, crushers, &c., and an ingot mould of soapstone of a curious form, which is still in use amongst the natives much further north for ingots of iron.

An interesting parallel to the ancient gold workings in Mashonaland is to be found by studying the accounts of the ancient gold workings of

the Egyptian gold mines in Wadi Allaga. The ancient Egyptians also extracted gold from quartz by means of crushing and washing, as we see from the process depicted in the paintings on the Egyptian tombs, and in any gold-producing quarter of Mashonaland, near old shafts and by the side of streams, innumerable crushing-stones are still to be seen, used anciently for a like purpose.

Diodorus tells us of the gangs of slaves employed in this arduous labour, and of the long dark shafts into which they descended. In the Mazoe district we entered several of these ancient shafts, and it is obvious here that not only for working the mines but for the construction of the massive buildings similar gangs of slaves were employed.

After describing the process of crushing and washing Diodorus concludes: 'They then put it into earthen crucibles, well closed with clay, and leave it in a furnace for five successive days and nights, after which it is suffered to cool. The crucibles are then opened and nothing is found in them but the pure gold, a little diminished in quantity.' Here we have an exact parallel to our clay crucibles at Zimbabwe. Also the heavy plating of metal with gold which was practised in Egypt was also known to the people of Zimbabwe, as the gilding on our spear-head demonstrates.

As Mr. and Mrs. Bent propose to follow up their investigations in Mashonaland by visiting Abyssinia during the ensuing winter, with a view to clearing up certain points connected with their recent expedition, regarding which more information is required, the Committee ask to be reappointed, and that a sum of 50*l.* be placed at their disposal for carrying on these researches.

Report of the Committee, consisting of Mr. E. SEWARD (*Secretary*), *the* MARQUIS OF BUTE, Messrs. G. T. CLARK, R. W. ATKINSON, FRANKLEN G. EVANS, C. TANFIELD VACHELL, JAMES BELL, *and* T. H. THOMAS, *and* Dr. J. G. GARSON, *appointed to report on the Prehistoric and Ancient Remains of Glamorganshire.* (*Drawn up by the Secretary.*)

THE work of registering the localities of the prehistoric and ancient remains of Glamorgan has proceeded, but owing to the inability of several members of the appointed Committee to act, and delays in consequence, few meetings have been held. All those objects or remains, however, which are known have been named on the register, and particulars concerning them will be filled in later.

Important help to the Committee's work has been rendered by two local scientific societies, viz., by the Cardiff Naturalists' Society, under whose auspices a valuable paper was recently read on the 'Ancient Inscribed Stones of Glamorganshire,' by Mr. T. H. Thomas, and also one by Mr. E. Seward on the formation of this record.

The Cardiff Amateur Photographic Society, by means of prizes offered to their members, have produced some hundreds of valuable original photographs of prehistoric and ancient objects in the county, most of such objects within the county having thereby been illustrated. This collection, which is believed to be the most extensive yet formed in any district, is stored at the Cardiff Free Library. The Corporation have given good aid to the work by important grants to the Prize Fund.

Eighth Report of the Committee, consisting of Dr. E. B. Tylor, Mr. G. W. Bloxam, Sir Daniel Wilson, Dr. G. M. Dawson, Mr. R. G. Haliburton, *and* Mr. H. Hale, *appointed to investigate the physical characters, languages, and industrial and social condition of the North-Western Tribes of the Dominion of Canada.*

Remarks on Linguistic Ethnology: Introductory to the Report of Dr. A. F. Chamberlain on the Kootenay Indians of South-Eastern British Columbia. By Mr. Horatio Hale.

The report of Dr. Chamberlain derives a special interest from the fact that it is a monograph devoted to the people of a single linguistic stock, or in other words to a people differing totally in speech from all other branches of the human race. In my 'Remarks on North American Ethnology,' prefixed to the Fifth Report of the Committee (1889)—which I venture in this connection to recall to mind—the fact was pointed out that 'in America the linguistic stock is the universally accepted unit of classification.' After explaining how, in my opinion, such stocks had originated, namely, 'in the natural language-making faculty of young children,' who in the earliest settlement of a new country had been left, orphaned and isolated from all other society, to frame a new language, and ultimately a new social system and a new religion of their own,[1] I added: 'From what has been said, it follows that in our studies of communities in the earliest stage we must look, not for sameness, but for almost endless diversity, alike in languages and in social organisations. Instead of one "primitive human horde," we must think of some two or three hundred primitive societies, each beginning in a single household, and expanding gradually to a people distinct from every other, alike in speech, in character, in mythology, in form of government, and in social usages.'

Since these remarks were written three publications relating to American ethnology, each of peculiar value and authority, have appeared. The earliest and in many respects the most important of these is the volume on 'The American Race,' by Dr. Daniel G. Brinton, Professor of American Archæology and Linguistics in the University of Pennsylvania. The general scope of the work is shown by its second title: 'A Linguistic Classification and Ethnographic Description of the Native Tribes of North and South America.' The author has condensed within the limit of 400 pages an immense mass of information concerning the numbers and locations, the physical, mental, and moral traits, and the languages, religions, and social systems of the tribes of the western continent. It is the first and the only comprehensive work embracing all the septs of the new world, and will doubtless long remain the standard and indispensable authority. Of 'independent stocks or families,' we are told, 'there are about eighty in North and as many in South America. These stocks,' the author adds, 'offer us without doubt our best basis for the ethnic classification of the

[1] See the Presidential Address of Prof. Sayce in the *Report of the British Association* for 1887.

American tribes—the only basis, indeed, which is of any value. The efforts which have been heretofore made to erect a geographic classification, with reference to certain areas, political or physical; or a craniological one, with reference to skull forms; or a cultural one, with reference to stages of savagery and civilisation, have all proved worthless. I select, therefore,' he concludes, 'the linguistic classification of the American race as the only one of any scientific value, and, therefore, that which alone merits consideration.'

The 'introductory chapter' of Dr. Brinton's work contains many valuable data and interesting suggestions. But I am disposed to think that his view of the general resemblance pervading the American tribes in their social institutions is rather a reflex of earlier opinions than a deduction from the facts collected with judicial and impartial accuracy in the subsequent chapters. Thus, while holding that Mr. Morgan's assertions on this subject were too sweeping, he yet remarks (p. 45) that 'Morgan was the first to point out clearly that ancient American society was founded, not upon the family, but upon the gens, totem, or clan, as the social unit.' In the next page, however, further consideration leads him to observe that this 'gentile system' is by no means universal, and that 'it is an error of theorists to make it appear so. Subsequently (on p. 99), in treating of the Dakotas, he states that some of the tribes of this stock had no *gentes*, while others possessed them with widely differing systems of descent; and he then adds his final decision on this point in terms which completely dispose of the elaborate theories of Morgan and his disciples. He holds that, according to the evidence we possess, 'the gentile system is by no means a fixed stadium of even American ancient society, but is variable—present or absent as circumstances may dictate.'

Another recent publication of great importance is the paper of Major J. W. Powell, the distinguished Director of the U.S. Bureau of Ethnology, on 'The Linguistic Families of America north of Mexico,' which appears in the 'Seventh Annual Report of the Bureau,' nominally for 1885–86, but published in 1891, and actually coming down to that date in its information. The terms 'linguistic families' and 'stocks' are used by the author as synonymous. He finds the total number of such stocks on the continent north of Mexico to be fifty-eight; and while he thinks it is not improbable that this number may on further study be reduced by the fusion of some of these stocks, it is equally likely, in his opinion, that the number in the list will be made good by the discovery of new stocks in portions of the region which have not yet been fully explored. A catalogue as complete as can now be obtained is given, not only of the families, but of their tribes and dialectical subdivisions, with their leading names and the various synonyms by which they have been known. Major Powell does not think it necessary to give a reason for adopting the linguistic classification. He evidently regards the question as settled since the appearance of Gallatin's great work, the well-known 'Synopsis of Indian Tribes' (1836), by the general acquiescence of ethnologists. His preliminary remarks are chiefly, but not entirely, devoted to linguistic subjects, and present many facts and conclusions—the result of twenty years' study—which students of ethnology will find of special value and interest. It should, of course, be kept in view that in reminding his readers that, 'after all, the Indian is a savage, with the characteristics of a savage,' he must be regarded as referring in strictness only to the tribes

north of Mexico, and that he is too experienced an ethnologist to hold that all savages are alike in their characteristics.[1] His paper, it should be added, is illustrated by a 'linguistic map,' which in clearness and fulness is a model of what such a map should be.

The third recent work of special importance in connection with this study is the monograph of Mr. A. S. Gatschet, the eminent linguist of the Bureau of Ethnology, on 'The Klamath Indians of South-western Oregon,' which fills two quarto volumes of over 700 pages each in the series of 'Contributions to North American Ethnology.' The work bears date in 1890, but was not distributed until the following year. It is doubtless the most complete and scientifically exact account of the character, language, and mythology of a people composing a single 'stock' that has ever been published. Of their social organisation less is told. The author had made large collections on this subject, but lack of space has compelled him to defer their publication. He has, however, told enough to enable us to compare the main features in the social life of these Indians, who are surely 'primitive' and 'typical' savages, if there are any such, with the systems devised by McLennan, Bachofen, Morgan, and other ingenious theorisers. Mr. Gatschet, as becomes an investigator, is strictly impartial, and has no special system to maintain; but by a simple statement of facts he is able in four lines to upset as many theories. 'The Klamath Indians,' he tells us, 'are absolutely ignorant of the gentile or clan system as prevalent among the Haida, Tlingit, and Eastern Indians of North America. Matriarchate is also unknown among them. Everyone is free to marry within or without the tribe, and the children inherit from the father.'

To those who possess Mr. Gatschet's volumes the comparison between their contents and those of Dr. Chamberlain's equally authentic and careful observations will be highly interesting. But probably to most students the comparison of this report on the Kootenays with the no less careful and accurate descriptions of the coast tribes of British Columbia belonging to the Tlingit, Tsimpshian, and Kwakiutl-Nootka stocks, as furnished to our committee by Dr Franz Boas in his successive reports, will be still more instructive. The notable difference of character which

[1] I may be allowed to quote here a note from my 'Ethnography and Philology' of the U.S. Exploring Expedition (p. 13), which has been thought worthy of citation by various writers on anthropological subjects:—'Nothing is more common in the writings of many voyagers than such phrases as the following: "These natives, like all savages, are cruel and treacherous"; "The levity and fickleness of the savage character"; "The tendency to superstition which is found among all uncivilised tribes"; "The parental affections which warm the most savage heart," &c. These expressions are evidently founded on a loose idea that a certain sameness of character prevails among barbarous races, and especially that some passions and feelings are found strongly developed in all. A little consideration will show that this view must be erroneous. It is civilisation that produces uniformity. The yellow and black races of the Pacific, inhabiting nearly contiguous islands, differ more widely from each other than do any two nations of Europe. The points of resemblance between the negroes of Africa and the Indians of America, even under the same latitudes, are very few. In delineating the character of the different races of the Pacific an attempt will be made, by contrasting them with one another, to show more closely the distinguishing characteristics of each.' And further on (p. 198), in the description of the tribes of Oregon, a remark to the same effect is made:—'To one ascending the Columbia the contrast presented by the natives above and below the Great Falls (the Chinooks and Wallawallas) is very striking. No two nations of Europe differ more widely in looks and character than do these neighbouring subdivisions of the American race.'

is pointed out in my remarks introductory to the Sixth Report (1890), on the authority of missionary records and official documents, is fully confirmed by Dr. Chamberlain's observations. The contrast between the very complex social system of the coast tribes and the simple organisation of the Kootenays is particularly striking. The whole social life and frame of government of the coast stocks are wrapped up in their totem or clan systems and their secret societies. Among the Kootenays, according to Dr. Chamberlain, 'totems and secret societies do not exist, and probably have not existed.'

It is satisfactory to be able to add that both Dr. Brinton and Major Powell, in their recent publications, have referred to the reports presented to the Association by our committee as records of the best authority. I may venture to affirm that they will retain this authority with a constantly increasing reputation, not merely from my knowledge of the talents and experience of the authors of these reports, but from the fact that they have based their researches and classifications on the only scientific foundation, that of language—or, more strictly speaking, of comparative philology—a basis which in modern anthropology is too often disregarded.

Two points of minor importance, but still of much interest, in Dr. Chamberlain's report seem to merit notice. His statement that, 'as compared with white men, the Indians, with rare exceptions, must be considered inferior physically,' may be misunderstood. As regards those Indians to whom it was intended to apply, namely, the Kootenays and their neighbours, it is undoubtedly correct; but the author had certainly no purpose of including in his statement all the aborigines of America. He is well aware that these, like the communities of the eastern continent, vary physically as well as intellectually, not only from stock to stock, but from branch to branch. Of the Iroquois Dr. Brinton, in his 'American Race' (p. 82), states:—'Physically the stock is most superior, unsurpassed by any other on the continent, and, I may even say, by any other people in the world; for it stands on record that the five companies (500 men) recruited from the Iroquois of New York and Canada during our civil war stood first on the list among all the recruits of our army for height, vigour, and corporeal symmetry.' The other recruits, it should be remembered, comprised great numbers of emigrants from almost all the nations of Europe.

In the First and Third Reports of the Committee (1885 and 1887) are given the reasons for believing that the Kootenays formerly lived east of the Rocky Mountains, and were driven thence by the Blackfoot tribes in comparatively recent times. Dr. Chamberlain's account of the Kootenay traditions confirms this opinion, and adds a curious and significant circumstance. 'The Kootenays,' he states, 'believe that they came from the east, and their myths ascribe to them an origin from a hole in the ground east of the Rocky Mountains.' My early studies of the myths of the Pacific islanders disclosed the true origin and meaning of the legendary stories which have been common among many peoples in ancient and modern times, from the early Athenians to the Marquesans and Iroquois, who have ascribed to their ancestors an autochthonous origin, bringing them literally from underground. These legends originate in the double, or we might rather perhaps say the threefold, meaning given in most languages to each of the words 'above' and 'below.' This point is fully explained in an article contributed to the 'Journal of

American Folk-lore' for July–September 1890.[1] It will be sufficient to say here that the words in question, when used by any islanders (and sometimes by coast tribes) in a myth ascribing a celestial or an underground origin to their ancestors, are found to have meant originally 'from the windward' and 'from the leeward.' When used by inland tribes they have usually signified, in the first instance, 'down-stream' and 'up-stream.' Thus the Iroquois have two traditions of their origin, the one purely historical and the other merely mythical—the latter derived from the former by a perversion of the sense of these terms. The former describes their ancestors as ascending the St. Lawrence River in canoes from the neighbourhood of Quebec to the southern coast of Lake Ontario, at or near Oswego. The mythical legend makes them literally 'come from below' by finding their way through an opening which led upward from a subterranean abode beneath a mountain near Oswego. So the curiously combined tradition and myth of the Kootenays inform us that, in their opinion, their ancestors formerly dwelt in some locality east of the Rocky Mountains, and had arrived at that locality by an earlier ascent, doubtless up the Saskatchewan River. That they had been steadily forced westward by their persistent enemies and supplanters, the warlike Algonkians of the powerful Blackfoot confederacy, seems clear from the concurring traditions of both parties.

Report on the Kootenay Indians of South-Eastern British Columbia.
By Dr. A. F. Chamberlain.

Introductory.

The present report contains a summary of the results of the investigations of the writer on behalf of the British Association for the Advancement of Science during the summer of 1891 in South-eastern British Columbia. The Indians visited were the various tribes of the Ki'tōnā'qa, or Kootenays, about whom comparatively little was previously known. They were studied in regard to physical characteristics, sociology, folk-lore, and language.

The investigations were conducted under all the difficulties incidental to scientific research in a new country, and the writer takes this opportunity of thanking Mr. Michael Philipps, the Indian agent, and his good friends in the Kootenay district who did all in their power to make his sojourn pleasant and to advance the objects of his visit. Particularly does he desire to express to the Hon. R. L. T. Galbraith, ex-M.P.P., of Fort Steele, his gratitude for the many courtesies shown him, and for the hearty manner in which he endorsed and encouraged the writer in his movements amongst the Indians; to Father Coccolo and the Sisters of the Mission of St. Eugène he returns thanks for their hospitality and the willingness with which they used their influence with the Indians on behalf of science. To Mr. David McLaughlin, of Idaho, his thanks are also due for turning to good use, in favour of the writer, the great influence which he possesses over the Lower Kootenay Indians, and for useful information concerning these aborigines.[2]

[1] *'Above and Below': a Mythological Disease of Language.* By H. Hale.

[2] To Dr. Franz Boas, of Clark University, Worcester, Mass., the writer desires to acknowledge his indebtedness for much kind advice, and to express his appreciation of his courtesy in placing at his disposal, during the preparation of this report, his manuscript vocabulary of the Upper Kootenay language.

As material is lacking for comparisons in certain directions, which naturally suggest themselves, viz., with the Shoshonian tribes of the region to the south, as regards language, and with these, and with certain Salishan peoples, with respect to physical characteristics, these questions must be deferred for consideration at another time. It may be stated, however, that from the examination of his material (only partially arranged) there appears to be no reason to displace the Kootenay from its position as a distinct family of speech.

I. ETHNOGRAPHICAL.

Country and People.

The Ki′tōnā′ɋa, or Kootenays, inhabit the country included between the Rockies and the Selkirks, stretching from the forty-ninth to the fifty-second parallel of north latitude, and watered by the Upper Kootenay and Upper Columbia Rivers and their tributaries. They preserve, however, a distinct recollection of having formerly lived east of the Rocky Mountains. The ethnic and tribal names are as follows :—

An Indian is called *āqkts'mā′kinik*,[1] and a Kootenay Indian, *tsɛn āqkts'mā′kinik*, *i.e.*, '*the* Indian.' The names possibly have reference to the origin of the Kootenays, according to their legend, from a hole in the ground, as the latter part of the word, *'mā′kinik*, may be explained as consisting of *ämāk* (ground), *-i-*, a connective vowel, and the suffix *-nik*, signifying 'people originating from, dwelling at, &c.' The Kootenay also call themselves *Ki′tōnā′ɋa*, the etymology of which is unknown. One Indian connected it with *hō′tōnā′ɋɛnē*, 'I am lean.' They are generally divided into two groups, viz., Upper Kootenays and Lower Kootenays, the subdivisions of these being as follows :—

I. Ki′tōnā′ɋa, or Upper Kootenay : (*a*) Aqki′sk·ɛnū′kinik (*i.e.*, 'people of the two lakes'), the tribe of the Columbia lakes, with chief settlement at Windermere, on the Lower Lake; (*b*) Aqk'ā′mnik (*i.e.*, 'the people of A′qk'ām,' as the region of Ft. Steele is called), the tribe of Ft. Steele and the Mission of St. Eugène, of whom a large number camp at a place called Bummer's Flat, Yākikāts; (*c*) Yā′k'ēt āqkinū′qtlē′ēt āqkts'mā′kinik, or Indians of the Tobacco Plains (Yā′k'ēt āqkinū′qtlē′ēt); these are better and more properly termed Aqk'āneqū′nik (*i.e.*, 'Indians on a creek or river'); (*d*) Aqkīyē′nik ('people of the leggings' ?), Indians of Lake Pend d'Oreille.

II. Aqkōqtlā′tlqō, or Indians of the Lower Kootenay (Aqkōktlā′hātl) River, partly in British Columbia and partly in Idaho.

The number of the Kootenay Indians is uncertain; they are generally set down at 1,000, half of whom are in British Columbia, the other half in the United States. The reports of the Canadian Indian Department from 1880 to 1886 give the number as about 400. Mr. A. S. Farwell, in a special report to the Legislature of British Columbia[2] in 1883, makes the following statement:—'The Kootenay tribe of Indians number about 800 men, women, and children, and are divided approximately as follows: 450 British Indians domiciled north of the international boundary line, and 200 American Indians residing in Idaho and Montana Territories;

[1] For the alphabet used in this report see pp. 589, 590.

[2] For a copy of this the writer is indebted to the kindness of the Hon. John Robson, Provincial Secretary.

the remaining 150 Indians are migratory, receiving their share of the annuities paid by the United States Government, at its agency on the Jocko River, in the Flathead Reservation, Montana Territory, and claiming to be British Indians when they wander north of the boundary line.' About 300 of the British Indians inhabit the valley of the Upper Kootenay and Columbia, the remaining 150 belonging to the Lower Kootenay. The Lower Kootenays, according to Mr. Farwell, whose information was derived from Mr. D. McLaughlin, 'number 157, divided as follows: 35 men, 34 married women, 39 boys, 32 girls, 4 widows, with 6 boys and 3 girls between them, and 4 widows without encumbrances.'

In 1887 Mr. Michael Philipps, the Indian Agent amongst the Canadian Kootenays, estimated their number as follows:—

Columbia Lakes	65
Lower Kootenay	160
St. Mary's	235
Tobacco Plains	30
Total	490

The report of the Indian Agent for June 30 last (1891)[1] states the numbers of 'the Kootenay Indians in British Columbia' to be as follows:—

Columbia Lakes	106
Kinbaskets	41
Flatbow	159
St. Mary's	312
Tobacco Plains	78
Total	696

Ethnic Names.

The Kootenays call the surrounding tribes with whom they have come into contact as follows:—

(*a*) Blackfeet. Sāntlā or Sāhā'ntlā (bad Indians). In the past the Kootenays had many wars with the Blackfeet, but joined them often in their buffalo hunts on the plains to the east. The Blackfoot country is called Tlā'wati'nak (*i.e.*, 'over the mountains'). The Blackfeet often visit the Kootenays now, and are hospitably received. Such a visit occurred in the summer of 1891.

(*b*) Cree. Gū'tskīā'wē (liars). A few Crees occasionally visit the Kootenays, chiefly in company with the Blackfeet. In the old days of the Hudson's Bay Company these two peoples came more into contact.

(*c*) Stonies. These Indians have a very bad reputation with the Kootenays, and are named Tlū'tlämā'ɛkā (cut-throats). Also Gūtlu'puk.

(*d*) Sioux. Kā'tsk·āgi'tlsāk (charcoal legs).

(*e*) Shushwap. Tlitkā'tuwū'mtlā'ɛt (no shirts). This name was given because, when the Kootenays met the Shushwaps first, the latter had no buckskin shirts (āqkā'tuwū'mtlā'ɛt).

(*f*) Okanagan. Ō'kinā'k·ēn. Some of these occasionally visit the Kootenays. About ten years ago several came to A'qk'ām. They are also known in Kootenay as *Kōkɛnū'k'kē*.

[1] This information I owe to the courtesy of Mr. Vankoughnet, the Deputy Superintendent of Indian Affairs, Ottawa.

(*g*) Kalispelm. Kā′nōqtlā′tlām (compress the side of the head). Some years ago the Kootenays and Kalispelms were very unfriendly towards each other.

(*h*) Colville Indians. KQōptlē′nik (those who dwell at KQōptlē′kī). Some intermarriages with these have taken place.

(*i*) Yakima. Yāā′kimā. A Kootenay explained this as meaning 'foot bent towards the instep,' but this seems a case of folk-etymology. Some intermarriage with Kootenays.

(*j*) Sarcees. Tsū′QōS or Tcō′kō, also Saksi′kwan. In the palmy days of the Hudson's Bay Company not a few Sarcees came into contact with the Kootenays.

(*k*) Nez Percé. Sä′ptēt. Said to be so named from the 'grass-baskets' which they make. Perhaps related to the word from which comes the name 'Sahaptin.'

The Kootenay name for 'white man' is *sūyä′pī*, in all probability a borrowed word (in 'Parker's Journal,' 1840, p. 381, the Nez Percé word for 'American' is given as *suēapo*). Another and an old word for white man is *nūtlū′qɛnē*, *i.e.*, 'stranger.' The Indians employ also (but rarely) the term *kämnū′qtlō āqkts′mā′kinik* ('white man'). For 'negro' the word is *kämk·ōk·ō′kōtl* (lit. 'black').

A Chinaman is called *Gōō′ktlām*. The Kootenays are much given to lording it over the Chinese, and not a few practically live on what they make out of them.

Senses and Mental Character.

As compared with white men, the Indians, with rare exceptions, must be considered inferior physically. The European, when inured to the climate, is capable of as great physical exertion and able to endure as many and as lasting hardships as the Indian. In running, jumping, wrestling, and other tests of strength, a good white man is more than the equal of a good Indian. There are, of course, exceptions, but the European, given equal chances at the start, can, as a rule, equal, if not always outdistance, his aboriginal rival.

Many of the Indians have large bands of horses, and some of them are farmers. The chief of the Fort Steele Indians is comparatively well off and has a good ranch. Some of the Lower Kootenays do a little farming also, but are much more migratory and restless.

As a rule, the moral character and behaviour of the Kootenays are very good, and the writer, from his residence amongst them of nearly three months, can confirm the good words that were spoken of them years ago by Father De Smet. They are moral, honest, kind, and hospitable, and it is only when imposed upon by bad Indians of other tribes, or by bad whites, that any of the worse traits of Indian character appear. But it is exceedingly difficult to judge of the nature of the Indian, and to determine wherein he differs from the white man. The mental character of the Kootenays is rather high, and the efforts that have been made to educate them are not without fruit. Too much credit cannot be given to the Government of the Province of British Columbia for the firm manner in which, aided by public opinion, they have enforced the law prohibiting the giving or selling of intoxicating liquors to the Indians. This is the first and most necessary basis for any development or betterment of the aborigines. Next comes the freedom from contact with lewd and dishonest white

men, which the Kootenays have enjoyed to a much greater extent than have many of the neighbouring tribes.

To educate a moral and sober people ought not to be too difficult a task, if the right methods are employed. The founding of the industrial school for Indian children at the Mission of St. Eugène, a few miles from Fort Steele, has already been productive of good results. The writer paid a visit to this school, and had the pleasure of inspecting the teaching, as well as of examining the building and the various appliances connected therewith. The English language is taught in this school, and the young Indians learn to read and to write in a remarkably short time under the guidance of the nuns who have charge of the school. There were about two dozen boys and girls in the school at the time of the writer's visit; they were neatly dressed, polite, and intelligent-looking, and the progress they had made during the few short months they had been there was very encouraging. This school well deserves all the support given to it by the Government, and it is to be hoped that the project of extending its usefulness so as to reach the children of the Lower Kootenays will meet with a proper measure of success.

The great difficulty in civilising the Indian has been to prevent the relapse into old tribal habits when the school is left behind. The career of the future graduates of the industrial school at St. Eugène will be watched with interest by all friends of the Indian, and Father Coccolo, the head of the mission, and the Sisters in charge of the school may be relied upon to do their share towards making the end good.

No opportunities offered themselves for making psychological tests upon the Indians, but quick perception and rapid judgment are characteristic of the better portion of these Indians, as their actions in hunting and travelling plainly show. The Indian A′mɛlū, although forgetting very often to take away some of the articles from a camp when a new start was made, had a remarkable memory for places. One day he left a knife belonging to the writer about halfway up a mountain some 7,000 feet high. The incident was forgotten by him for the time being; but, on being asked many hours afterwards where he had left the knife, he described the place in great detail. On another occasion he left a knife in the woods by the side of the trail, and after we had made a journey of 150 miles and back, and had been absent from the spot a whole month, he was able, on our return, to pick up the knife with hardly a moment's hesitation.

The Kootenay Indians, especially the young men, are gay and lively, enjoying themselves as much as their white friends, fond of horse-racing and bodily exercise. They are of a very inquisitive nature, and the Indian A′mɛlū would run down to the river-bank and stand staring for almost an hour at the steamboat every time it passed the camp. The rest of the Indians were just as curious. The Indian A′mɛlū went (for the first time in his life) on a trip up the river on the steamboat with the writer, and the young fellow was so proud that he could hardly contain himself. No doubt he is now whiling away the winter hours by relating his experiences to his friends.

The writer had occasion to notice two excellent exhibitions of Indian character; in one case of pride and triumph, in the other of anger and disappointment.

A young Indian had been convicted of a crime and sent to jail at New Westminster, where he remained some months. Owing to the exertions

of a clever lawyer, his conviction was quashed on a technicality, and the authorities were obliged to return him to Fort Steele, where he belonged. The writer saw him the day after his arrival. He was dressed in all the finery he could command, and took the greatest pleasure in parading himself about and letting people see that he knew he had won a triumph over the whites. He was in the very highest state of pleasurable excitement, and continued in this frame of mind for a long time.

The other case was that of an Indian of about sixty years of age whom the writer was measuring. The Indian, however, after two or three measurements had been taken, demanded a large sum of money, and, on being refused, pushed the instrument away from him, and, angrily muttering, went outside the store, where he had been standing, sat down on the verandah in front, where he remained all the afternoon, glowering and muttering, and doing his best to impede matters. He continued in this morose mood for days, and even at the expiry of a month would not have anything to do with the writer.

There is also another case in point. While the writer was at Barnard, B.C., he visited Mr. David McLaughlin's often, and one morning, while seated parleying with the Indians, a middle-aged Indian suddenly entered the house, threw his hat on the floor in a most excited manner, and for twenty minutes poured a perfect flood of abuse and threatening on the head of the writer, accompanied by most expressive gestures. After he had unburdened himself of his wrath, he picked up his hat and departed. Several similar, though not quite so animated, exhibitions of anger came under the writer's notice during his stay in the Lower Kootenay, most of them being traceable to the Indian trouble at Bonner's Ferry, Idaho, which had aroused the resentment of the Kootenays.

While in the territory of Chief San Piel, of the Lower Kootenays, one day the chief and some dozen Indians came into the writer's tent and, seating themselves around him in a circle, demanded a large tribute for having intruded into their territory. A refusal to comply with the outrageous demand led to a very interesting display of Indian resentment and anger, as made known by speech and gesture, the faces of some of the savages being given at times an almost demoniacal expression, and their gestures just stopping short of actual assault. Still, in spite of these disturbing outbreaks, which sometimes occur, the white man who behaves himself is perfectly safe amongst the Indians, and need fear no treachery.

The Indians have a keen sense of the ridiculous, and go so far as to laugh at the misfortunes which befall their fellows. If an Indian is thrown from his horse, misses the animal he shoots at, trips up and falls down, his mishap is always greeted with laughter by the bystanders. A few hours after the excited speech of the Indian at McLaughlin's, the writer was engaged in measuring another of the same tribe, when the Indian suddenly rose to his full height, drew his knife from his sheath, and made a motion to strike the measurer, which somewhat disconcerted the latter, who, however, was almost immediately reassured by the loud laughter of the Indians who were present. The Indians take great delight in tricks such as this.

A favourite amusement of the Lower Kootenay Indians on Sundays is furnished by horse-running. All the horses are assembled in a large open space near the camp, and the Indians form a large circle round them, and, provided with long whips, they drive the horses to and fro for an hour or so, laughing and yelling to their hearts' content. Even the little

boys take part in this sport. They also take great delight in breaking stubborn horses, and the whole camp looks on until the young man has succeeded in controlling his animal, guying him unmercifully if he makes mistakes.

The Kootenay Indians have marked artistic ability, although picture-writing upon rocks, &c., appears not to be found in their territory, or, if found, is not attributed to them. Their skill in ornamentation appears in their various objects of dress and the implements of the chase. The writer took the care to have a series of drawings made by Indians (young and old) who had in no way received from the whites instruction in the draughtsman's art. Very good maps of the country in which they lived were made by these Indians, who seemed quite to have grasped the idea contained in such a delineation. Some of them were also able to recognise with ease the various physical features prominent in the printed maps of the Kootenay district. Their drawings of weapons, implements, &c., were excellent, and those of the Indian A'mELū, in particular, would never be suspected of being the product of aboriginal genius. Pictures of houses, railway trains, &c., have a certain conventionality that is characteristic of savage races. Several of the Indians were able to draw an excellent and easily recognisable picture of the little steamboat that plied up and down the Columbia River. In their drawings of human beings especial stress is laid upon the distinguishing features, and any peculiarity or abnormality is brought out with full force. Thus a Stony Indian woman has no nose, a Chinaman has an immense single braid of hair, a white man an enormous beard, a certain Indian a colossal nose, and the like.

Colour Vocabulary.

The colour vocabulary of the Kootenays, as tested by a card of 'Diamond Dyes,' is as follows:—

White, *kämnū'qtlū.*
Black, *kämk·ōk·ō'kōtl.*
Red, *kānō'hōs.*
Crimson, Cardinal red, Magenta, Cardinal, Violet, } *kēīkōp.*
Dark violet, *tsōō'q'nōkaQā'mēk.*
Fast pink, *kō'pqāqtlē'ēt.*
Fast brown, Maroon, Dark brown, } *āqkā'qtlakō'QōQ.*
Green, Dark green, Fast bottle green, Light blue, } *kā'qtlū'īyi'ť'ka.*
Olive green, *tō'Qā kā'qtlū'ē'tka.*
Blue, *yāmi'nkan.*
Orange, Yellow, Old gold, } *käma'qtsē.*
Scarlet, *yāwō'Enēk.*
Variegated, *gāktlē'tl.*
Half white, Half black, } *kämk·ō'k·ōguitlQā'tlētl.*

The colour perceptions of these Indians would appear from these names to be fairly well developed. The explanations of these colour-names, which are no doubt compounds, have not yet been possible. The prefixes *käm-* and *yā-* are worthy of note, and the words for 'white' and 'black' may possibly be related to those for 'snow' and 'fire' respectively.

The following colour-names for horses may be given:—

Kämnū'qtlū k'ā'tla Qā'Etltsin, a white horse.
Kämk·ōk·ō'kōtl „ a black horse.

Kā'tlāqā'tlētl	*Etltsin*,	a horse half white, half black (Pinto).
K'ka'sɛnō'stlām	,,	a roan horse.
Ka'nōkāyū'kaqō	,,	a 'buckskin' horse.
Ka'nōtstlā'aka't'	,,	a 'blue' horse.
Kä'makts'k·ō'wāt	,,	a sorrel horse (lit. 'yellow hair').
I'ntcūk k·ō'wāt	,,	a mouse-coloured horse (lit. 'mouse hair').

Social Organisation.

The social system of the Kootenays seems a simple one. As far as could be learnt totems and secret societies, so characteristic of some other British Columbian peoples, do not exist, and probably have not existed, amongst them.

The head of each tribal or local community was the chief (*nāsū'kwēn*, 'the good one'), whose office originally was hereditary. Women were not allowed to become chiefs, and it is probable that the age of thirty had to be reached before the chiefship could be held. One method of selecting the chief appears to have been this: All the men, women, and children gathered together around a large fire. The medicine men then conferred with the spirits, and in some mysterious way the chief was named. In the time of the great buffalo hunts a 'buffalo chief' was elected, who had authority over all during the expeditions. The selection of the chiefs by direct election has been of late years introduced by the authorities of the Roman Catholic Church, whose influence is now greater than that of the old chiefs, and whose power is much more feared by the Indians than theirs. When the chief wished to consult with his people he called them in a loud voice to come to his large tepee. It is probable that from early times a sort of advisory council existed. Each of the divisions (Columbia Lakes, Fort Steele, Kootenay Lake, Tobacco Plains) has its own chief; in the case of the Kootenay Lake tribe there is a deputy-chief also, and the Tobacco Plains Indians possess two chiefs.

Isidore, the Fort Steele chief, inherits his dignity from his father Joseph. The chief (by right) of the Lower Kootenays is said to have refused the position, giving as a reason for his action that wars were now all over, the buffaloes were dead, and there was now nothing left for a chief to do.

Slavery (*g·ä'naqā'ka*, 'a war-party,' *tcï'kuōtɛ'mātl*, 'a slave') was customary in the old days, and the Kootenays had amongst them many Blackfeet women and children, who were captured in their wars with that nation. A curious custom, which has existed from time immemorial amongst the Kootenays, is the payment by the relatives of the debts of a deceased person. Debts outstanding for ten years have been known to be paid in this way.

Terms of Relationship.

As far as ascertained, the Kootenay terms of relationship are as follows:—

Father, *titō'nam* (said by male). *sō'nam* (,, ,, female).
Mother, *mā'ɛnam*.
Grandfather, *papā'nam*.
Grandmother, *titē'nam* (said by male) *papā'nam* (said by male or female).
Great-grandfather, *ā'tsemītl*.

Great-grandmother, *ā'tsemītl.*
Uncle (father's brother), *qā'nam.*
„ (mother's brother), *hatsā'nam.*
Aunt (mother's sister), *kōōkt.*
„ (father's sister), *tē'tltēt.*
Father-in-law, *nuwa'spātl.*
Mother-in-law, „
Husband, *nūtlā'kɛnā.*
Wife, *titlna'mū* (=old woman).
Brother-in-law, *skāt.*
Sister-in-law, *ātcā'wāts.*
Brother (elder), *tatē'nam.*
„ (younger), *tcā'nam.*
„ *kō'kōqā'mātl.*
Sister (elder), *tsō'nam.*
„ (younger), *nānā'nam.*
„ (general term), *ātlitskē'tlnam.*
Cousin (m.), *ātlkō'kōqā'mātl.*
„ (f.), *ātlatlitskē'tlnam.*
Son, *āqk·ātlē'nam.*
Daughter, *sūī'nam.*
Nephew (brother's son) = brother.
„ (sister's son) = brother.
Niece (brother's daughter) = brother
„ (sister's daughter) = brother.
Grandson, *papā'nam ; ā'tlāqk·ā'tlē.*
Granddaughter, *papā'nam ; qātlē.*
Married man, *tlātlī'tēt.*
Unmarried man, *tli'ttlātli'tēt.*
Marry, *hō'nātlā'qanē, hōnā'tlātli'tinē* (I marry).
Widow, *tlūtlū'mātl.*
Widower, „
Orphan, *na'nkā.*
Young unmarried man, *ntstā'hātl.*
„ „ woman, *nāū'te.*
Boy, *ntstā'hātl na'na.*
Girl, *nāū'tē na'na.*
Infant, *tlkā'mū.*
Twins, *kāsū'kō.*
Woman, *pā tlkē.*
Man, *ti'tk'āt.*

Marriage (*hōnā'tlātli'tinē*, I am married).

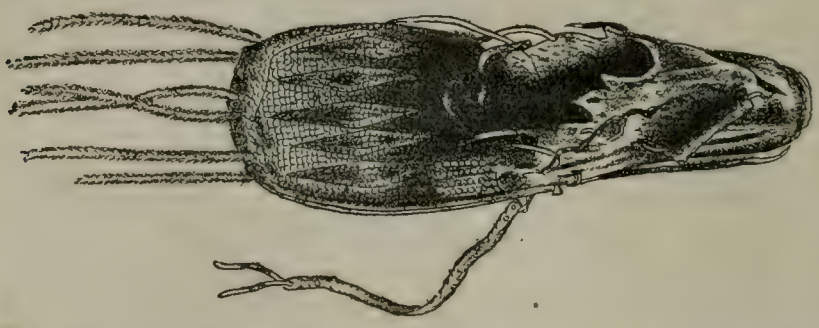
The social position of woman amongst the Kootenays seems to have been about the same as that which she held in the surrounding tribes. In the old days polygamy seems to have been in vogue, and wives were purchased by presents of horses, &c. The marriage age for girls was fifteen; for young men, twenty. Intermarriage of first cousins appears not to have been allowed. The preliminaries to marriage were as follows:—The young Indian went at night to the lodge where slept the object of his affections, and quietly lifting up the blanket, to make sure, lay down beside her. The girl's people soon found him there, and threats were made. The young man's father meanwhile inquired where his son was, and, on being told that he was in such-and-such a lodge, went thither with his friends and discovered the young people together. The girl then left, and went with her husband to his own people. The latter was at liberty to send back his wife to her relatives within a year if she turned out to be bad or he was dissatisfied with her. When guilty of adultery she was punished by having one of the braids of her hair cut off by her husband. A divorced woman was allowed to marry again, and widows also. Descent seems to be traced through the mother.

Children (*tlkā'mū*, young child).

The Indians are fond of their children, and rarely punish or beat them. The children are usually very shy of white men, but amongst themselves are merry and lively. Parturition is easy amongst these Indians. Delivery was hastened by the efforts of several old women, who seized upon the pregnant woman and shook her. The after-birth was always hung on a tree. Mothers carry their children either in shawls at their backs or in cradles. The Kootenay cradle (*āqkink·ō'mātl*) is made of deerskin drawn over a thick board, about 3 feet long, and tapering from $1\frac{1}{2}$ foot at the widest to 6 inches at the lower end. Near the top is a flap which can be fastened over the head of the child, which, when in the cradle on the mother's back, is in an upright position. The

cradle is often ornamented with beads, bits of fur, silk, &c. In olden times the cradle was a piece of board to which the child was fastened

Fig. 1.—Indian cradle, ornamented with bead-work and strips of weasel fur. The original is 37 inches long by 14 inches broad (at the widest part).



with buckskin thongs. The cradle is supported by straps around the breast and a band around the forehead (*see* fig. 1.)

Adoption.

Adoption into the tribe by marriage, or by residence of more than a year, was in practice. When the parents of small children died the relatives came, each taking a child and bringing it up as his own. The elder children seemingly had to take care of themselves. A very friendly feeling between brothers and sisters existed, and the latter were well taken care of on the decease of their parents.

Property and Inheritance.

Private property in land was unknown, the country belonging to the tribe collectively. The Lower Kootenays still make, through their chief, a demand for money of any stranger who intrudes upon their domain.

The hunter had no absolute right in the product of his skill in the chase; it was distributed amongst the camp in order that all might have food.

Women could hold property as well as men. The horses were the property of the grown-up male children, as well as of the father, and could be gambled away by any one of them. The lodge seems to have been secured to the widow and children on the death of the father; the women inherited also the kettles and other utensils, besides their saddles, blankets, 'parfleshes,' &c. The horses, canoes, weapons, &c., went to the male children, if of age. In early times it seems that the dead man's relatives swooped down upon the lodge, soon after his death, and appropriated the property pretty much as they pleased. The exact nature of this seizure could not be ascertained. If the dead man left no relatives a 'strong man' of the tribe took possession of his property.

Crime.

Stealing (*na'iinē*, he steals) is little practised by the Kootenays; and though amongst them for months, when they had every chance to pilfer

from him, the writer never lost even a trifle. In the olden times it seems not to have been punished, and probably existed but to a very slight extent. Adultery was not severely punished. In case of murder the relatives of the victim were bound to avenge his death on the slayer. Members of the murderer's family were also liable to be killed. A wer-gild was customary; the compensation depended upon the rank and importance of the victim. This compensation did not, however, entirely relieve the slayer from danger of being killed by members of his victim's family.

Religion and Superstition.

The sun-worship of the Kootenays, as described by Dr. Boas ('Report,' 1889, p. 848), which seems to indicate a belief in an over-ruling and beneficent spirit—though this is not certain—is confirmed. The belief that the dead go to the sun was strong with the 'pagan' Indians. They also believed that the dead would come back from the sun at Lake Pend d'Oreille, where the Indians will meet them some time in the future.

The Kootenays believe in the existence of spirits in everything animate and inanimate; even little stones, bits of rag, shavings of wood, have their *nipi'k'a* or *tcāk'ä'ps*, as these spirits are called. These spirits can go anywhere, through glass, wood, or any substance, as through air. The touch of the *nipi'k'a* causes death and disease. At the death of Indians their spirits may enter into fishes, bears, trees, &c.; in fact, into anything animate or inanimate. While a man is alive his *nipi'k'a* may exist in the form of a tomtit, a jay, a bear, a flower, &c. The *nipi'k'as* of the dead can return and visit their friends; and while the writer was at Barnard, B.C., one Indian declared that the night before the spirits of his children had come to see him. The spirits appear very frequently in the folk-tales.

In the olden times sacrifices appear to have been made to the *nipi'k'as* of the mountains and of the forests to secure success in hunting, and to appease them when angered. The language of the *nipi'k'as* differs somewhat from the ordinary Kootenay, but the writer was unable to ascertain in what respects, or to obtain examples of it. A great or strong man has many spirits (*see* also p. 562 of this report).

Medicine-men, or Shamans.

In the old days there were many medicine-men amongst the Kootenays, and they were very powerful, as it was their business to commune with the spirits. In the camp they had special lodges, larger than the rest, in which they prayed and invoked the spirits, who often would make their appearance in the form of a bird or the like in response to their entreaties.

There existed, until recently, a tree in the Lower Kootenay region, in Northern Idaho, from which, on two successive occasions, Indians had jumped off in obedience to the promise of the medicine-men that they should be able to fly like the birds if they did so. In the presence of the assembled camp, men, women, and children, several Indians were hardy enough to do this, which was, of course, certain death to them. The invocation of spirits by the shamans now survives amongst the Lower Kootenays only.

These shamans were also the doctors of the tribe. They treated the

sick by pressure upon various parts of the body, by pinching, &c. They also practised blowing upon the patient, and extracted the supposed cause of the malady by suction with the mouth. Blood-letting at the wrist was also in use. The shaman was called *nï'pik'ak·ā'k·'ā*, from his having to do with the *nipi'k'as*.

Death and Burial.

The Kootenays usually buried their dead in shallow holes amidst the rocks and boulders, and often left them exposed to the air. Sometimes they buried them on low lands, subject annually to be covered by the river at high water. In the early days the Indian was buried with all his finery, and the members of the tribe seemed to have followed in the funeral procession. Before the Church authorities put a stop to it, the Indians used to betake themselves to the hills and shriek terribly over the dead. They appear to have taken good care of their dead, and never disturbed the graves of their people. It is impossible to obtain osteological material on account of the strong prejudice the Indians have in this matter.

Painting and Tattooing.

The Upper Kootenays do not now paint (*gï'tɛnū'stik*) or tattoo (*kātlkū*) their faces or persons, except in very rare instances. In the past, however, they practised the same very much. It is said lovers' wooings and challenges to fight were made known by painting the face in a peculiar manner, and the answer was conveyed by the same means. Some of the Indians are tattooed on the arms with small black dots, often accompanied by black lines. In one case, which the writer investigated, it turned out that the tattooing was done by Lum Kin, a Chinese doctor, to cure a sore arm. The Indians, however, admitted that in the past they had similar practices.

Numbers of the Indians have on their arms one or several circular scars, evidently made by burning. These, the Indians said, were produced by pressing a hot tobacco-pipe of stone to the flesh. No reason for so doing was assigned.

The Lower Kootenays are still much given to painting the face, ears, neck, and exposed portions of the breast in gaudy colours. Many, whom the writer saw, had their whole faces, necks, and ears daubed thickly over with bright red paint. Some had the face painted red and the forehead yellow; others, again, had the colours laid on in bands of red and yellow, giving them a weird appearance as they danced by the huge fire at night.

Not the men alone, but the women also, were thus decorated, and with the same variety. The children, as a rule, seem not to be so much bepainted as their elders. Some of the Indians contented themselves with a few daubs here and there. One *métis*, who assured the writer that he was a 'Boston man,' and not an Indian, was seen the very next day with as much paint on as the most Indian of them all.

The red ochre used for paint is called *nāmi'ta*. Other terms for 'paint' are: *kānō'su'mmē*, red paint; *kāmā'ktsu'mmē*, yellow paint. The word *gï'tenū'stik*, 'to paint,' is derived from *nūs* or *nōs*, the radical of *kānō'hōs*, 'red,' that being *the* colour.

Music and Song (*hō'nāwasqō''mėk*, I sing).

The absence of musical instruments is very noticeable amongst the Upper Kootenays, but they appear to have possessed several in the past. Among these were a sort of reed pipe and a kind of flute (?) made of the leg-bone of a large species of bird. The Lower Kootenays still possess the Kootenay drum, made as follows:—A rather large stick is bent into a circle by the aid of fire, and over this is stretched, tambourine fashion, a piece of deer-skin. The Aqk·ayē'nik Kootenays are said to be the only ones who now make these drums (*kitāmō'hōtl*); they are beaten with a wooden stick called *kitā'mōhō'mōtl*. In their gambling songs the Lower Kootenays use wooden sticks, called *āqsē'ēt*, with which they beat upon a log.

In the old days the Kootenays had very many gambling, dancing, and medicine songs. The Indians, under mission influence, have abandoned most of these, their places having been taken by the religious exercises of the Church. The children at the mission sing well, both in Indian and in English. In the evening the older people sing mission songs in their native tongue. Amongst the Lower Kootenays some of the old songs still survive.

While travelling on horseback some of the younger Indians sing refrains like this: *Tō tō tō tō! tum tum tum! tā tā tā tā! tai tai tai tai!* accompanying it with rhythmic motions of the hands or with slaps with the hand upon the flanks of the horse. Another refrain, chanted with an infinite variety of inflexion and intonation, is the following:—

Hai yā! hā hē yau!
Ē yā! hā hā hai yau!
Hē yā! hō yō! &c.

The Indian A'mɛlū was very fond of repeating in rhythmic fashion the word *tcina'tlūē'tɛm*, which he declared to be nothing but 'cultus wawa' (Chinook jargon for 'mere chatter' or 'idle utterance'), having no signification.

The Lower Kootenays are very much in love with gambling, which vice, through the efforts of the missionaries, has been entirely suppressed amongst the Upper Kootenays. In the gambling dance they chant *Hai yā! hai yā! hai yā hē*, repeated an infinite number of times, interspersed with yells of *hō hō! hā hā! hē hē hai hai! hū hū!* &c. Another gambling refrain is *ī ī ī! yā ē e e!*

The gambling consists in guessing in which hand one (on which a ring of bark is left) of two sticks of wood is hidden. The players sit in two rows facing each other, and a number of them keep beating on a log in front of them with sticks, while the sticks are passed from hand to hand. From time to time some of the players sing or contort their limbs in various ways. In its essentials the game is the same as the Chinook game described by Paul Kane ('Wanderings of an Artist,' p. 193), who has not failed to note 'the eternal gambling song *he hah ha!*'

The following songs were obtained from Paul, a Tobacco Plains Kootenay, and were stated by him to be very old:—

I.

Kī'tāmū'qōtl	kā'kūwē'tl	titk'āt	pā'tlkē.
Drum	*dance*	*man*	*woman.*

Kā'tlkòk'ātlma'ᴏᴇnam na'matiktci'tlnē
Kissing *give.*

Sē'tis tlä'kītläk nātlkōk'ā'tlmāᴏa'tlnē.
Blankets *divers things* *kiss.*

Nā'matiktci'tlnē yū'nākā'nē k'ä'psins.
Give *many* *things.*

They beat the drum and dance; men and women kiss; they present blankets and other things; they kiss and give many things.

II.

Ni'titlānā'mnā tsᴏātla'nkōᴏō'tlnē tsi'sini'nkōᴏō'nātlkā'ᴇnē
He makes a lodge *makes a big lodge* *and invokes spirits*

na'ksak.
the marten (Mustela).

III. *Medicine Song.*

Kīka'ᴏnā'mnan ni'sinwisᴏā'tlnē na'kinē kāki'ksī ni'pik'ā'is.
The Indian covers himself with a blanket *swims* *speaking* *his spirit.*

Tlāti'k'mi'tētl kāki'ksī ni'pik'ā'is. Tsᴏā'dlᴏāka'iyᴇkā'mik.
Enters the top of the lodge speaking *his spirit.* *Rolls over on the snow(?)*

Paul elaborated this song thus:—An Indian is crouching in the corner of his lodge beneath blankets, invoking the spirits. Soon the spirit enters through the top of the lodge, passes beneath the blanket, and enters the Indian, who then flies away on high; by-and-by returns, and, sitting under the blanket, causes the spirit to depart again.

IV. *Medicine Song.*

Ta'mōᴏō'tlnē tsitlwanū'knanū'kanāmnā'mnē.
They beat drums *sing very much.*

Yū'nāk'ä'psī k'ä'psins kᴇtcū'kwāt ᴏā'tkina'kinē.
Many *things* *get* *he recovers.*

Drums are beaten, songs are sung, many gifts are made, the things are removed, and the man recovers.

V. *Gambling Song.*

Ka'tlūwā'tsinam yū'nākā'nē ke'skaᴏmi'tētl k'ä'psin.
Gambling *many* *are lost* *things.*

K'k'ā'tlaᴏā'ᴇtltsin sē'tis āqka'tūwū'mtlāᴇt tā'wō āqktcā'mātl
Horses *blankets* *shirts* *guns* *knives*

ni'tlkō.
money.

K'ā'pē k'ä'psin ne'skaᴏmiti'tlnē.
Every *thing* *lost.*

VI. *War Song.*

Nētlāwa′tinak ni′natlūtlūni′sinam.
Across the mountains they go far away.

Ätnō′nītli′tlnē sā′ntlā ä′tkōnka′tlawūsqō′nīya′mnē.
They are much afraid of Blackfeet ?

Ätslō′nītli′tlnē sā′ntlā; tlsqā′tlāī k′ā′tlaqā′ɛtltsin.
They are much afraid of Blackfeet; they will steal horses.

Ätnū′pslāti′yitlkā′nīki′tinē.
They keep singing a long time.

Ni′nātlhō′tlōni′sinam tlā ōpkā′tlōni′sinam.
They go far away; they cross the mountains again.

Nō′kwankik·i′tlāqk′nī′yam. Ta′aqas ätkā′kaskini′tlnē.
Kill all the buffaloes. Enough of singing.

This song Paul explained as follows:—The Indians cross the mountains to go to the distant Blackfoot country, where there are great prairies and many buffaloes. The Indians are much afraid of the Blackfeet. The youths form circles and sing. The Kootenays are much afraid of the Blackfeet. They are going to steal horses. They sing for a long time. Then they hasten to return across the mountains, having finished killing buffaloes.

VII. *Children's Song.*

Kitki′nitl kānē′hē tlä′kītläk kā′wiskā′kanā′nam.
Kiktci′kinā′mnam ätsli′tkini′tlnē kā′ktlinkâ′iyam.
Ätsli′tkini′tlnē k·ā′tla 'tlkā′mū niktci′kētl.
Hinnēn nētstā′hātlna′na ätāwū′′tē āqkinū′tlāms.
Nāū′t′na′na ätni′nsī kīyū′k′mū′tlēs ätni′nsē āqkinū′tlām.

Paul gave the following explanation of this song:—The children join hands in a circle, and bending the knees assume a sitting posture, the whole weight of the body resting on the legs below the knees. They keep rising up and sitting down, never actually sitting on the ground, however. One of them closes his eyes, and the game consists in the others stepping on his toes, &c., and pretending to be women, snakes, guns, or the like.

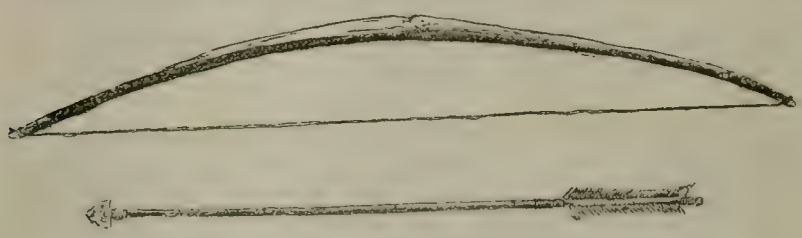
Hunting (*hō′nānā′qē*, I hunt).

The Kootenays have always been great hunters. In former times they used to cross the Rockies to join the Blackfeet and other tribes in the great annual buffalo hunt. Since the disappearance of these animals they have been forced to confine themselves to the pursuit of bears, deer, wolves, and the smaller fur-bearing animals. The Indians are very skilful in the chase, and it is said that in the old days certain families hunted only some particular animal; the bear or the beaver, for example. The flesh of most of the animals killed is eaten by the Indians, and the hides are disposed of to the whites. The Upper Kootenays kill a large number of skunks (*qā′qas*), which they sell to the Chinese miners, who use them for medicinal purposes.

Since the introduction of firearms amongst the Indians, the old bows and arrows have in great part disappeared. Some of the children use them to shoot birds, and here and there may be still seen a few old men with bow and quiver slung across their backs (the quiver being made of skin, and often profusely ornamented with beads, strips of fur, &c.). In using the bow the Kootenays hold it sometimes horizontally, sometimes perpendicularly. The arrow rests between the first and second fingers of the left hand, which grasps the bow-stick, while the notch-end of the arrow is held between the thumb and first finger of the right hand.

The bow-stick (*āqktlā'kūō*) was made of cedar (*ĭtsᴇnā'ᴇt*, Thuya gigantea) or maple (*mitskik*, Acer glabrum). The bow-string (*t'āwū'm'kā*)

Fig. 2.—Bow and arrow (with flint point) made by Indian. The bow is 28½ inches long.



was made of the sinews (*āqkink·ā'tlkā*) of various animals (chiefly of the deer), and sometimes of strips of skin. The arrows used for shooting birds were entirely of wood, with a thick, blunt end. Other arrows (*āqk*) had points (*nātlkō'tsap*) of bone or stone, and, latterly, of iron obtained from the whites. The stone arrowhead (*nātlkō'tsap*) was of flint (*āqkā'tskō*) obtained by the Lower Kootenays from a mountain about twenty miles from Barnard, B.C., and by the Upper Kootenays of the region about Fort Steele from the vicinity of Sheep Creek. The point of the arrow is called *āqkink·ā'kā*, the feather *āqk·ā'n'k·ō*, the notch *āqk·ā'n'k·āk*, the quiver *iāts'āk*, or *ā'qkank·ā'nam*, the whole bow and arrows *āqkō'k'mātlihēt t'ā'wō*. Long ago the Lower Kootenays are said to have caught ducks by means of a pole, to which was attached a net made of the fibre of the plant known as *ā'qkōtla'kpis*. The Indians used to lasso the 'fool hen' (*kiā'wāts*) by means of nooses made of the same material.

It was customary for the hunter to distribute the product of his prowess amongst his relatives and friends, and this hospitality was almost a law of the tribe. It is not quite certain whether an Indian would kill a bear or a fish into which he thought one of the spirits of his departed relatives had gone.

Fishing (*nātlā'ktlauwa'tē*, he fishes).

The Lower Kootenays are, to a great extent, canoe and fishing Indians. The Upper Kootenays, for the most part, on account of their situation, are less given to travelling by water or to the procuring of fish, excepting salmon (*sūwā'kᴇmō*), as a food supply. Many methods of catching fish are in use, of which the following are the chief:—

Before the advent of the whites, the Indians fished with a hook (*tcō'wāk*) made of a bit of bone fastened to a piece of wood, the whole having much the shape of an ordinary hook. To this was attached a line

made of the fibre of *ā'qkōtla'kpis*. For hooks to catch small fish the spines of a species of gooseberry called *kisyī'tin* were sometimes employed.

Fishing through the ice was practised thus: Over a hole cut in the ice was laid a branch or stick of wood, upon which was let down a branch having two prongs, the ends of which were tied together, and from them hung the hook and line of *ā'qkōtla'kpis*. This method of fishing was termed *nā'ūsāntlū'ktlūkwā'tsenē*.

Another mode of obtaining fish in the winter time was to pound on the ice with a club or heavy piece of wood, and so drive the fish into the shallows near the shore, where repeated blows stunned or killed them. This was called *gā'kpakī'tōwī'tɛqō'mōtl*.

Gaffing (*gūā'kōmī't'wūm'k·ō'mō*) by means of a large hook attached to a slender branch or pole is now much practised by the Indians, who are very skilful at it.

The Lower Kootenays, depending upon fish as a chief source of their food supply, have certain devices for obtaining them in large quantities. The chief of these are the dam or weir and the basket-trap.

The first of these (*āqk'wū'kqō*) is a sort of dam of sticks and wicker-work built across a stream or at the entrance of a 'slough,' so as to prevent the escape of the fish when the water falls. Attached to these dams are often wicker-work traps, cone-shaped, sometimes 10 feet long by 3 feet wide, into which the fish fall and are caught. Fishing by means of this is called *wā't'kō'tlik*.

The basket-trap (*yā'ka*) is of wicker-work and cone-shaped (often as large as 10 × 3 feet): within it is ingeniously placed or worked another cone, called *ā'qkitlwī'is yā'ka* ('the heart of the *yā'ka*'), or *yā'ka na'na* ('little *yā'ka*'), which effectually prevents the exit of the fish, while affording them an easy entrance. Along one side of the *yā'ka* are placed rings of bark, generally three in number; to these are attached stout strings, which are held by three or four Indians. To fish with the *yā'ka* is *nā'witskā'enē*.

There are three kinds of fish spears in use amongst the Kootenays. The first, called *āqktla'qa*, closely resembles the spear of the Eskimos; the second, *ā'qkinū'kmāk'*, has three fixed points like a trident; the third has a point of wood, headed with metal, shaped like an arrow-head, to which is attached a string, so that the point is released when a fish is struck and can be retrieved. The third sort is used for salmon and other large fish. To spear fish is called *gū'āk·ō'mō*.

FIG. 3.—Head of fish-spear called *āqktla'qa*. The original is 18½ inches long by 2⅛ inches at widest part.

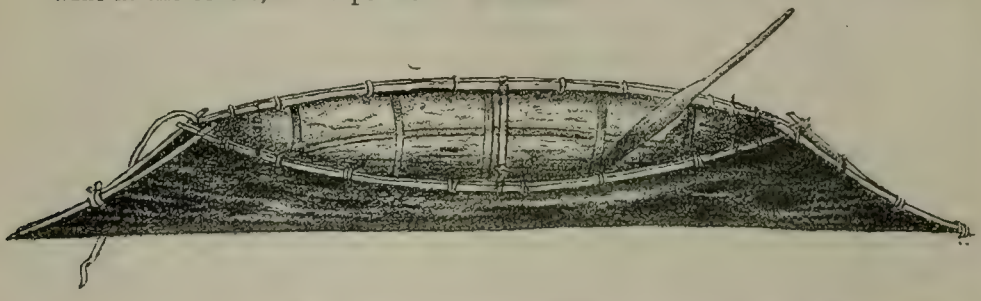
The Lower Kootenays dry immense quantities of the fish called *mā'tit* and *ōpā't'* for use during the winter. The fish are dried (*ki'tkani'tltlitl*) on stages called *ā'qkūwā'skō*, which are erected near the lodges.

Canoes.

The Kootenays have three names for canoes: *tcï'k'Enō*, a canoe made of pine or spruce bark; *stā'tlām*, a 'dug-out'; *yāk·tsō'mētl*, a term for other than dug-out canoes. A steamboat is *ā'qkink·ō'k·ō yāk·tsō'mētl* ('fire canoe'), and a large ferry-boat is called *stā'tlām*.

The bark canoe of the Kootenays is of peculiar construction. It is made for the most part of white pine (*ā'qkām*) or spruce (*gï'sitsk·ā'dl*, Picea alba) bark (*āqk'wōk*), with the outer side turned in and chipped off, so as to be fairly smooth. The upper rim, of about 4 or 5 inches in width, is made of birch bark. The Lower Kootenays use the bark of the tree called *ā'qkām* to make their canoes. The sewing is done by needles of bone (*dlō*), and split roots serve as thread. The pitch (*i'dlūwas*) used is obtained from several of the coniferæ. The boat is much shorter at the top than along the keel, and at both ends runs down towards the keel, terminating in sharp points (*ā'qkō*), thus rendering it quite unique in appearance. The rim around the top is made of bent strips (*āqkō'k'yū*) of hard wood, and is well secured by lashings of split roots and bark fibre. The edges of these strips cross at the ends. From the ends to the keel run two binding strips (*āqkū'nwōk*) for each end of the boat, which are fastened in the same way. The boat, besides being pitched, is often plastered over with a sort of mud (*ä'māk*). The inside framework consists of longitudinal strips (*āqkï'kdlūk*) on the bottoms and along the sides, and the curved strengtheners (*āqkō'dlmā*) running from top to top along the bottom and

Fig. 4.—Canoe of Lower Kootenay Indians. This drawing is after a model made by Chief Eustan. The model canoe is 22 inches from tip to tip by 4½ inches wide at the centre, and is perfect in its details.



up the sides. The bark fibres or strips used for tying and lashing the various parts together are called *näp'tsū'nqā*. The thwarts, three or four in number, are called *ā'qkE*. The paddle (*dlï'sin*) is generally of cedar; the blade is called *āqkä'm*, and the handle *āqkā'n*. The paddler kneels upon a number of flat pieces of cedar or other similar wood tied together termed *gōï'nidl*.

These canoes are very 'cranky,' but the Indians can navigate one of them in the wake of a large river steamer with ease. The canoe is anchored by sticking the handle of the paddle into the mud of the shore and tying the boat to it by a string of bark, &c. The Lower Kootenays make very good models of large canoes, reproducing in miniature the features of the original (*see* fig. 4).

Houses.

The houses (*ā'qkītlā'nam*) of the Kootenays consisted of a framework of converging poles (*āqkits*) over which were laid the skins of various

wild animals. The number of poles used varied from five or six to nine or ten. There was no particular separation of men and women in the lodges; communal houses were unknown. In the old days it was considered a grave offence to let the fire in the tepee go out. Larger lodges for the chief and for the medicine-man were the rule. Lodges were also constructed of the rush called *tänātl*.

Sweat-houses.

The sweat-houses (*wisē'yātl*) were made of willow sticks bent over one another so as to form a dome-shaped structure from $2\frac{1}{2}$ to 4 feet high and some 4 feet in diameter. This dome is covered with blanket, grass, bark, &c. A hole is dug in the ground in the centre, in which the bather crouches. Near to the sweat-house is built a fire, in which stones are heated red-hot and placed within the *wisē'yātl*, when water is poured upon them, and the naked Indians stand the almost suffocating temperature for a long time, until suddenly they rush out and plunge into the stream close by. The Kootenays are very fond of these sweat-baths, and the writer has seen more than a dozen of the *wisē'yātl* in close proximity on the banks of one of the many creeks of the country.

Implements, &c.

The use of the name *āqkū'tātl* for both 'flint' and 'axe' seems to indicate of what material the Kootenays made axes in the past. Axes were also made of deer or elk horn called *ā'qkātlē'ēt*. Knives (*āqktcā'mātl*) were of similar materials. Needles and awls (*tlō'ō*) were made of the sharpened small bones of the leg of the moose (*nē'ts'nā'pkū*) and other animals. Hammers (*pu'pū*) of stone are still in use.

Manufactures.

Water-tight baskets, made of split roots and known as *yi'tskī*, are still manufactured by the Lower Kootenays, but the art appears to be nearly

Fig. 5.—Root-basket. The original is $5\frac{1}{2}$ inches high, $5\frac{1}{2}$ inches across bottom, and $3\frac{3}{4}$ inches across top.

Fig. 6.—Moccasin, beaded and ornamented. The original is 10 by 5 inches.

lost amongst the Upper Kootenays of British Columbia. The larger

varieties of these 'kettles' are called *yi'tskī*, the smaller *yi'tskī na'na*. The terms *yitskī'mī*, *ā'tcū*, and *ā'gatlā'ɛk* are also in use, the last amongst the Lower Kootenays. These root vessels are often stained and ornamented in curious fashion. The Kootenays also make baskets or 'kettles' of birch bark. These, which are sometimes very large, are called *nā'hēk*.

All the Kootenay women make moccasins, gloves, and shirts from the skins of various animals, and these are often artistically embroidered and ornamented with silk and beads; also pouches, bags, &c., of like

FIG. 7.—Gold dust bag. Original is $7\frac{1}{2}$ inches long by $2\frac{3}{4}$ wide: made of buckskin, and ornamented with bead-work.

FIG. 8.—Ochre-bag of Indians, heavily beaded. Original is $5\frac{1}{2}$ inches by $3\frac{1}{2}$ inches.

FIG. 9.—Glove, 'made to order,' by Indian woman. Original is $8\frac{1}{2}$ inches by 4 inches.

material. The skins used, after being deprived of the flesh and fat adhering to them, are stretched over hoops of willow and a fire built under them. After this treatment they are tanned with deer's brains, so that they become very soft and pliable.

DRESS (*ā'qkōktlā'ntēs*, his clothes).

The dress of the Kootenays varies considerably. Very many of the women and a large number of the men have, to a greater or less extent, adopted civilised attire. But perhaps the majority of the men still cling to the old blanket-legging (*āqk'atu'ktluk*), the blanket (*sē't*) formerly so much in use, and the customary moccasins (*tlā'ɛn*). The shirt of buckskin (*āqkā'tuū'mtlāɛt*) is replaced by one procured from the store, which, as a rule, is worn over the breeches and not tucked in. The Lower Kootenays in dress, as in several other respects, are more primitive than the Upper. Some few of them dress like white men, but in summer most of them go bare-foot and bare-legged, having frequently no other garment than an old shirt. In this guise they wade through the swampy meadows or urge their horses over the grassy plains.

The girls and women are, as a rule, attired like the whites. The boys wear nothing but a shirt and a very narrow breech-clout, *tɛskāp'ukwā-nī'mō*. In the winter the dress of the Lower Kootenays varies, some clinging to the old blanket, others dressing like the white man.

Those Kootenays who do not go bare-headed wear felt or straw hats

(*āqkā'iyūkwā'nam*, felt hat; *ātlā'tlqō*, straw hat) adorned with various charms or ornaments. The Indians frequently pierce these felt hats with many holes or whiten them with a sort of pipeclay.

In the olden time the dress of the Kootenays was different. The skin of the moose (*nē'ts'nā'pkū*) furnished them with shirt and leggings. They also made ornamented shirts of buckskin, and the women had a special dress for festal occasions. The Lower Kootenays still make these fine shirts, which are often punctured with holes and highly ornamented with bead-work, bits of silk, and strips of otter and weasel skin. The moccasins were made the same as those in use now. The Lower Kootenays used to make them out of the skin of the horse. No hats were in use. The Indians wore broad bands of wolf (*kā'qkin*) or coyote (*skī'nkūts*) skin around the forehead and sides of the head, leaving the top bare. This probably survives in the narrow band of cloth which some of the older Indians still wear in like manner. More recently, the Upper Kootenays made little caps of skunk (*qā'qas*) skin, and very beautiful ones from the skin and feathers of the loon (*nōk'tlu'kwēn*).

Very many of the Indians wear a breech-clout even when they assume the European dress.

Hair-dressing (*hōtcū'ktlāmā'mēk*, I comb my hair).

Many of the Kootenays wear their hair long and flowing. Numbers of the Lower Kootenays wear their hair cut short: this is less common amongst the Upper Kootenays, although favoured by the Mission. Most of the adult Kootenays braid (*hō'nitlī'tltlūkwa'tcktlanā'mēk*, I braid my hair) their hair in one or more braids (*kā'tltlūkwa'tcktlām*, my braid), and ornament these with silk, bits of fur, &c. Three braids, one down the middle of the back and one over each ear, are common. In the old days the rule for both men and women was two braids, one over each ear. The hair was not cut.

Ornaments and Charms.

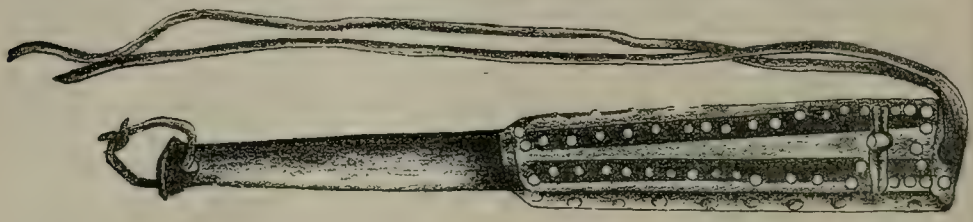
The Kootenays are profuse in the ornamentation of their persons. From the hats, belts (*āqk'ā'mtam*), shirts, and leggings of the men are suspended twisted silk, beaded cords, gay ribbons, strips of fur, &c. Strings of weasel (*mā'iyūk*) fur appear to be most in favour, one Indian having as many as twenty dangling from various parts of his dress. Around the

Fig. 10.—Knife-sheath of leather studded with brass tacks. This is possibly of white workmanship.

hats strings of beads, silk, strips of fur, and bands of bright-coloured cloth are worn. The belts, pouches (*ā'qkōtlā'kō*), moccasins, &c., are often finely worked with designs of leaves of plants, animals, &c., in silk or beads. From the necklace (*ā'na*) and belt are suspended bits of ore or

wood, perforated shells (obtained from the store), and little trophies of the chase. Feathers of the owl and chicken-hawk are highly prized as orna-

FIG. 11.—Indian quirt or whip. Handle of wood, 15½ inches long by 2½ at widest part, studded with brass tacks. The lashes are 19½ inches long.



ments. Earrings (*ā'qkokwā'tskak'ū'nām*) of shells with serrated edges are much worn by both men and women, and some seem to have their ears disfigured by reason of these ornaments.

FIG. 12. Necklace of Kootenay Indian. Contains two bears' teeth, a few beads, and in the centre a stone charm. The material is dark, slaty stone. The teeth are 2½ inches long, and the stone 2¼ inches.

Many of the Indians still carry about their persons the horse-shoe steel (*āqktē'mōtl*) for striking fire, which the Hudson's Bay Company distributed long ago, and the nippers (*tlūqtlū'tlāhä'pkinē'mōtl*) used for extracting the hairs on the face and body.

The Indians are fond of brass finger-rings (*ā'qkōkwa'tsitsqa'i"nām*). One young fellow wore six: three (on first, third, and fourth fingers) on the right hand and three (on first, second, and fourth fingers) on the left.

Many of the ornaments are undoubtedly charms, and the Indians are very loth to part with these. One blind Indian had more than a dozen bits of stone, wood, fur, &c., besides a sort of needle made of the small bone of the leg of a grizzly bear. Bear's teeth and claws are much worn, either in necklaces or pendent from the hair or some part of the dress.

In the olden times necklaces of *āqkū'p'mak*, a shell found in the rivers of the Lower Kootenay region, and wristlets of the same material were worn. Men, women, and children wore earrings made of these shells, the child's ear being pierced very early in life. No evidence of the existence of labrets, nose ornaments, or the practice of knocking out certain of the teeth could be found.

Tobacco, Pipes.

The Indians call store tobacco *yā'k'ēt*, and their own sort, made of the leaves of certain willows and plants, *tcakā'ū*. They have a remembrance of having obtained tobacco from the south-east. The principal plant which they use for making their native tobacco is that known as *tcakū'wōk* (the kinnikinnik plant, *Arctostaphylos uva-ursi*). The pipe-stems (*āqkū'tla*) are made of *a'qkumō"wōk* (*Viburnum opulus*) and other woods. The pipe itself (*kōs*) is made of stone procured from the Lower Kootenay. These pipes differ very much in form and size, and are but little ornamented. Very few of them are now made. The Indians are very fond of cigarettes (*īyū'q'ā'iit*), and in making them prefer to use printed paper (*see* figs. 13, 14).

Food (*kikētl*).

Much of the food supply of the Kootenays is now purchased. They are very fond of such sweet things as sugar, sweet-meats, jellies, and preserves. The Upper Kootenays obtain the refuse when cattle are killed by the Chinamen and the ranchers. The Lower Kootenays will eat horses, and have been known to eat the dead bodies of cattle that have been drowned and have remained for days in the river. The Kootenays do not eat skunks (*qā'qas*), cats (*pūs*), frogs (*wɛ'tāk*), crows (*qā'qā*), ravens (*kō'kwēn*), certain hawks, various kinds of woodpeckers, owls, robins (*tci'kɛkū*), plover (*kā'ūē'ts*), jays (*k·ōk·ū'sk·ī*, blue jay; *wā'kōks*, white jay), although the children occasionally eat the red woodpecker (*mā'ɛka*), and a few Indians will eat the owl (*k'ū'pī*), and the hawk called *i'ntlāk* (*Accipiter Cooperi*). The Indians eat the eggs (*ā'qkimū'qan*) of a few birds whose flesh they do not use as food, such as the *yi'kets'nā* and the *tcōk'tlātltlā*. The Kootenays have the reputation of being enormous eaters, and the writer's experience fully corroborates this. The Kootenays have the disgusting habit of eating the vermin (*hō"kē*) which infest their heads, and even the chief has been seen picking the lice from one of his tribesmen's head and devouring them with evident relish.

Food Plants.

A large portion of the food of these Indians is of a vegetable nature, consisting of berries, roots, moss, &c. The following are the principal:—

Berries: *sk·ō'mō*, service-berry (*Amelanchier alnifolia*); *kisyī'tin* (*Ribes oxycanthoides*), wild gooseberry; *āqkō'kō* and *gātstlāgō'kō*, raspberry;

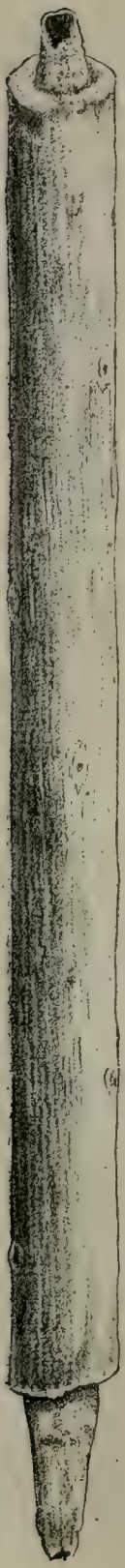
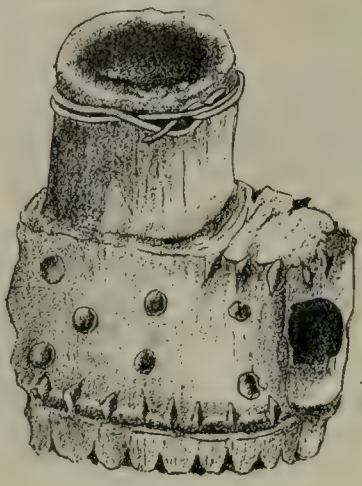


FIG. 13.—Carved and pitted Indian pipe. Natural size. Broken at top, but held together by wire. The stem of this pipe is much longer than the figure in the engraving.



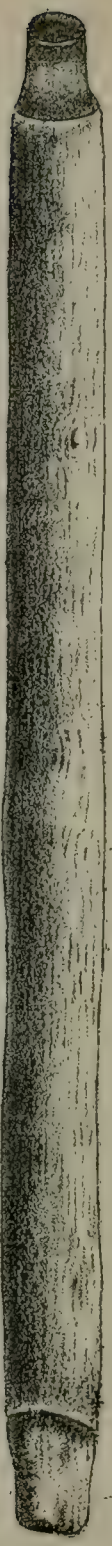
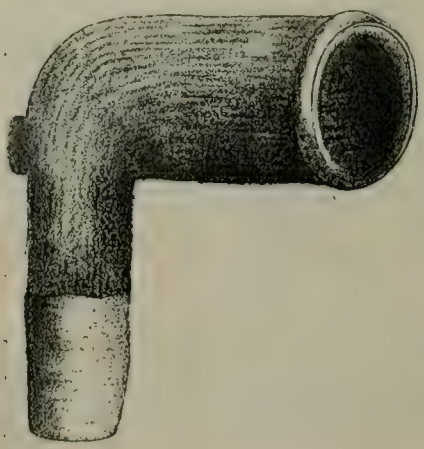


FIG. 14.—Indian pipe, bowl, and stem. Natural size. Bowl of stone with lead covering at junction with stem.



tlāwī'yātl, huckleberry; *nā'mkōknū'mātl* (*Ribes viscosinum*), species of gooseberry; *āqkōkōp'* (*Fragaria virginiensis*), strawberry; *gōpā'tētl* (*Shepherdia canadensis*), soap-berry (little eaten by the Kootenays, but much by the Shushwaps); *nāhōk*, Oregon grape (*Berberis aquifolium*); *gō'tlwā* (*Rosa pisocarpa*) rose-hips; *nūpqā'mōtl* (*Vaccinium cæspitosum*).

Roots: *āgō'wātl* (*Allium cernuum*), wild onion (eaten raw or boiled); *nitlkū'mā* (*Lilium philadelphicum*), root of the orange lily; *pu'lūlū'tsā* (spec. ?), boiled and eaten; *wū'mātl* (*Heracleum lanatum*); *nāsā'it* (*Calichortus elegans*), boiled and eaten; *āqkitskākam* (spec. ?); *gūtskō'kun* (spec. ?), chewed, but not eaten.

Varia: The mushroom, called *wa'tāk ā'qkātlā'qāēs* (frog's ?), is eaten by the Blackfeet, but hardly ever by the Kootenays. The hairy tree-mosses, known as *ā'ttlā*, *emgō'tlna* (*Evernia vulpina*), are eaten after being left in the ground under a hot fire for some days.

The gum and inside bark of the larch *g''ō'stet* (*Larix occidentalis*) are much relished, as also is the sap exuding from the *a'qkitstlā'tlutlā'tl*, or 'gum-wood.'

For making tea the leaves of the shrubs called *āqkōtla'kpēkā'nam* (*Linnæa borealis*), *kitkāūtli'tlkāqō'mik*, *gākīāqā'pū'ūk* (*Ceanothus sanguineus*), *gōpātē'tlūwōk* (*Shepherdia canadensis*), *gustlūtlā'tl* (*Juniperus communis*), *mā'ttā* (*Mentha canadensis*).

Plants used Economically.

From the fibre of a species of hemp *ā'qkōtla'kpis* (*Apocynum cannabinum*), fishing-lines, ropes, &c., are made. The spines of the *kisyī'tin*, or wild-gooseberry, served as hooks for small fish. The bark of *gīānūqtlā'ūwōk* (*Elæagnus argentea*) is used to make ropes for catching horses. The wood of the maple, *mitskēk* (*Acer glabrum*), was in the old days used to obtain fire by friction. From the plant *emgō'tlnā* (*Evernia vulpina*), by boiling, a red dye for moccasins, root-baskets, &c., is obtained, and the little seeds called *gākū'tlwan* of the plant *gākū'tlwanmō'ōs* (*Purshia tridentata*) furnished a reddish dye.

Plants Admired for their Smell or Beauty.

The plant called *āqkū'ōktlū'qūnā'ɛtēt* is much admired by the Kootenays on account of its scent. They may often be seen applying it to their nostrils, or, where it is found in great abundance, rolling about on the ground in evident delight. They fill bags with the plant called *anā'nam* (*Matricaria discoidea*), and use them as pillows. The flowers of the *k'sō'k'nō'k'yōk* (*Arenaria pungens*) are much admired. The plant *nisnā'pā'tl* (*Oryzopsis asperifoliens*) is thrown on the fire in large quantities on account of its good smell.

Medicinal Plants.

The principal vegetable remedies of the Kootenays are as follows:—

For sore eyes: The inside bark of the birch, *āqk·ūā'tlūwōk* (*Betula papyrifera*), boiled; the peeled and boiled root of the *nāhō'kōwōk*, or Oregon grape; the bark of the shrub *mō'kwō'k* (*Cornus stolonifera*) boiled; the root of the *wū'mātl* macerated and boiled; the plant *nāmtlā'sūk* (*Cicuta maculata ?*) pounded in a mortar; the burnt leg bones of deer pounded in a mortar.

For horses the Indians chew the tops of the plant *mitskō'kōtli't'nā* (*Apocynum androsæmifoliens*), and spit it into the animal's eyes.

For consumption, coughs, colds, sore chest, &c.: Strong decoctions of the various tea-plants, *wū'mātl*, *mā'ttā* (*Mentha canadensis*), &c.; the grease in the tail of the otter; plasters made of the leaves of the tea-plant.

For horses the plant *āqkinū'ktlū'qōnā'ɛka* (*Bigelovia graveolens*) is used.

For belly-ache: *Gā'imāwitstla'kpēk* (*Spiræa betulifolia*) boiled in water; *nā'mā''t* (*Alnus*).

As a purgative: A decoction of the root of the *nāhū'kōwōk*, or Oregon grape plant.

For wounds, cuts, bruises: *qā'tl* (*Balsamorrhiza sagittata*) boiled and applied to hands, &c.; the leaves of the *ātlū'mātl* (*Populus tremuloidea*) macerated, boiled, for burns, &c.; the pounded and macerated bark or leaves of the various tea-plants; the gum or resin of several of the coniferæ.[1]

Disease (*sā'nitlqō'nē*, he is sick).

A very stringent and well-enforced law of the Province, which has the cordial approval of the settlers and of the Roman Catholic missionaries, keeps the curse of liquor from the Kootenays, and not a little of their present good character is due to this fact. By the common consent of travellers, missionaries, and settlers, the morality of these Indians is very high, and they are practically free from venereal diseases, and the licentiousness prevalent amongst some of the coast tribes is unknown. The experiences of Mr. Robert Galbraith, who for some years acted as the medical adviser to these Indians, bears out to the full this statement. The institution of the sweat-bath and other helps to personal cleanliness has its good results.

The Indians suffer most from consumption and allied affections, and diseases of the eye. The latter are mostly caused by the smoke of the lodges, and terminate not infrequently in complete blindness. Scrofula is also prevalent. Some cases of goître have been noted (one, that of a woman, came under the writer's observation), due, it is said by the settlers, to the immoderate use of snow-water. The Indian dogs are stated to be subject also to goître.

Running sores on the face and neck and in the ears are rather common, especially with the children, and the cause of a recent death was given as cancer of the brain supervening upon a sore in the ear. Some of the Indians are disfigured by warts; one deaf and dumb individual had his hand covered with them, and in the case of a little boy the face, thick with warts, was gradually being eaten away by cancer.

Toothache, though very rare, is not unknown, and Mr. McLaughlin stated that he had known several Indians to suffer terribly from it.

Besides their numerous native remedies, the Indians have frequent recourse to the supplies of the white man and the Chinaman.

The writer met with two deaf mutes and two blind Indians. Amongst the Lower Kootenays there is said to be an hermaphrodite, who keeps constantly in the society of the women.

Illustrations of Articles of Kootenay Manufacture.

The drawings which accompany this report I owe to my brother, T. B. A. Chamberlain, who made them, at my request, from the originals.

[1] For the determination of the scientific names of plants, &c., the writer is indebted to the courtesy of Professor John Macoun, of the Geological Survey, Ottawa, Canada, to whom he begs to return his thanks.

II. Mythology and Folklore.

Astronomical.—The moon (*natā'nik, k'tci'tlmī'yıt natā'nik*) is regarded as a man, the sun (*natā'nik*) as a woman. There was no sun in the beginning, and after the Indians had vainly endeavoured to discover it the coyote (*ski'nkūts*) was successful in making it rise above the mountains. Another version makes the chicken-hawk (*i'ntlāk*) cause the sun to rise, and the coyote, getting angry, shoots an arrow at the sun, but misses, with the result of setting the prairie on fire and making him run for dear life.

The moon is said to have been found by the chicken-hawk. The man in the moon is an Indian, who once chopped wood all the days of the week (including Sunday), whereupon the moon came down and seized him, and he has been in the moon ever since. This myth may be of European origin.

The stars are mostly Indians, who from time to time have got up into the sky. The Great Bear is called *tlā'utlā* (*i.e.*, grizzly bear), and was an Indian woman. Being a female grizzly she is at times very angry, and the stars in the tail are Indians, upon whom she has seized. The Milky Way is *āqkɛmā'is ɑā'ɛtltsin*,' 'the dog's trail.'

The thunder (*nū'ma*) is caused by a great bird that lives far up in the sky. The lightning (*nāqkā'tlimū'qūāti'tlēk*) is made by the shooting of its arrows.

At first there were no clouds (*āqk·ātl*). The daughter of the coyote married the thunder, and her father gave her the clouds for a blanket.

Ethnic Origins, &c.—The Kootenays believe that they came from the East, and one of their myths ascribes to them an origin from a hole in the ground east of the Rocky Mountains. Another account says the Kootenays sprang up from the hairs of the black bear (*ni'pkō*), which fell on the ground after he came out of the belly of the great fish which had swallowed him. There were no women at first. By-and-by an Indian went up into the mountains, and from a spirit who lived there received the first Kootenay woman.

Horses were made as follows :—A medicine-man took a piece of stick, made it into the shape of a horse, and threw it away, whereupon it became a horse.

The Indians have a belief that the white men get their cattle from the sea. They say the white men go every year to the shore of the Pacific Ocean to receive the cattle which come out of the waters.

Deluge Legend.—*Sukpē'kā* (a small grey bird, species ?), the wife of *i'ntlāk* (Accipiter Cooperi), is forbidden by her husband to go to a certain lake, to drink of its waters, or to bathe in it. One day her husband goes out after deer and repeats the warning before leaving. *Sukpē'kā* busied herself picking berries, and, what with climbing the mountain and being exposed to the hot sun, she feels very warm, and goes down to the lake. Suddenly the water rises, and a giant called *yāwō'ɛnēk* comes forth, who seizes the woman and ravishes her. *I'ntlāk* is very angry when he learns of this, and, going to the lake, shoots the monster, who swallows up all the water, so there is none for the Indians to drink. *I'ntlāk's* wife pulls the arrow out of the giant's breast, whereupon the water rushes forth in torrents, and a flood is the result. *I'ntlāk* and his wife take refuge on a mountain, and by-and-by the water sinks to its proper level.

In a variant of this legend the 'giant' is a 'big fish.' *I'ntlāk* sees the

conduct of his wife, kills her and the monster; it is the blood of the fish that causes the deluge; and *i'ntlāk* escapes by climbing to the top of a tree. The scene is localised as the Kootenay River, near *A'qk'ām* (Fort Steele).

In another variant the 'giant' is a 'lake animal,' and *i'ntlāk* stops the deluge by placing his tail in the water, the flood ceasing to rise when it had reached the last row of spots on his tail. Hence the spotted tail of the chicken-hawk.

Fish swallows Bear.—Long ago there was in the Kootenay River, near A'qk'ām (Fort Steele) a huge fish. One day this fish swallowed the black bear (*ni'pkō*), who had been an Indian (?). The bear remained in the belly of the fish about two months, when he was vomited out. The bear lost all his hairs, which, falling to the ground, became Kootenay Indians. The big fish is finally killed by the bird called *yāmä'kpātl*, a species of woodpecker.

ANIMAL TALES.

The folklore of the Kootenays consists mainly in animal tales. Following is a sketch of the principal characters and their actions:—

Animals.

Bear (*black*).—Given above.

Bear (*grizzly*).—Appears frequently in tales; is often deceived by the coyote, who induces him to attempt to cross a creek on a log, and when the bear is half-way over shakes the log, causing him to fall into the water and be drowned. Then the coyote boils the grizzly in his kettle, which tumbles over, and the coyote, getting angry, throws the whole into the river. In another tale the grizzly (*tlā'utlā*) is killed by the spirits.

Beaver (*si'nā*).—Appears in tale with turtle. Throws turtle into river. Beaver grease is a dainty of frequent mention in the stories.

Buffalo (*ni'tltsik*).—Appears often in tales with the coyote. Asks the coyote to smoke his (buffalo's) pipe, which he does, and gets his mouth burned in consequence. Buffalo-skulls (inhabited by spirits) lying on the prairie are often mentioned in the tales.

Caribou (*na'qanē*).—Appears in tales with the coyote or the wolf. Is killed by the coyote, and in another tale by the tomtit.

Chipmunk.—Two species of chipmunk appear in the tales. The one called *k·ō'tcātc* is killed by the owl and the frog, who put him into 'sour dough.' The other, known as *nā'mtlāɛt*, appears as an unimportant personage in the tale in which the toad and eagle take part.

Coyote (*ski'nkūts*).—The coyote is the chief figure in Kootenay mythology. His principal exploits and adventures are as follows:—He sets out with the chicken-hawk to find the sun, gets angry, and shoots an arrow at the sun, thereby starting the first prairie fire; kills the caribou, the owl, the white-tailed deer, the grizzly, the cricket, the moose, &c. He is thrown into the fire by the chicken-hawk and gets his coat singed. Smokes the buffalo's pipe and gets his mouth burned. Quarrels with his wife, the dog, and kills her. Is represented as carrying his younger brother, the cricket, about with him. The cricket has a broken leg, and one day the coyote breaks his own leg to be like him. The cricket tries to injure the coyote, who finally kills him. After being for a long time supreme amongst the animals the coyote is beaten and killed by the

fox, who takes his place. Among the services rendered by the coyote to the Indians was the appeasing of the spirit of the mountains, who became angry and killed all those who started to hunt in his domains. In return for this benefit he was given a wife from the tribe, and from that time to this the Indians have been allowed to hunt in peace.

Deer.—The white-tailed deer (*tcū'pk'ā*) is killed by the coyote. The young deer are cheated in a race by the frogs.

Dog.—The dog (*qā'ɛtltsin*) appears as the wife of the coyote, who kills her in a fit of anger.

Fox.—The fox (*nā''kɛyū*) is often represented as carrying a root-basket. Scares the skunk by whistling; kills the wolf and restores him to life again; induces the wolf to try to beat the shadow of the sun; kills the coyote, and becomes chief of all the animals.

Moose (*nēts'nā'pkū*).—The male moose (*nēts'nā'pkū*) is killed by the coyote, and the female moose (*tlā'wō*) by the tomtit.

Mountain Lion.—The mountain lion (*sūā'ɛ*) is feared by many of the other animals, especially by the skunk, whom he at last killed.

Rabbit.—The rabbit (*gī'anū'qtlū'm'nā*), with the snow-bird (*niskā'ɛt*), kills the female moose and brings some of the meat to the frog.

Skunk.—The skunk (*qā'qas*) is represented as a very clever animal, and is associated often with the fox. He carries a root-basket, and is afraid only of something that whistles; is scared by the fox's whistling and runs off, but afterwards tries to kill the fox; is finally killed by the mountain-lion.

Squirrel.—The squirrel (*t'a'kāts*) appears a few times, and in one of the tales is killed by the spirits.

Wolf.—The wolf (*kā'qkīn*) appears often in the tales. Kills the tomtit and the caribou. Is occasionally carried by the coyote; is killed by the fox and brought to life again; wagers the fox that he can outrun the shadow of the sun, but fails to do so; and a long quarrel with the fox results.

Birds.

Duck.—Some ducks (*gūā'qtlā*) are seen by the coyote on a little lake; by-and-by they rise up, and the lake dries up. The coyote afterwards pulls out some of the ducks' feathers, so that they cannot fly too high.

Eagle.—The eagle (*gūā'k'ānu'kūāt*) appears in a tale along with the toad and hawks. Is found sitting on a tree by a star, and is killed by the latter.

Goose.—The goose (*kāqū'tlōk*) is represented in one tale as a child eating dirt.

Grouse.—The 'fool-hen' (*kūā'wāts*) has a large family of young ones: these are stolen by the coyote, who puts them in his sack. They escape, however, by scratching holes in it. The 'ruffed grouse' (*t'ā'nkūts*) takes the place of the 'fool-hen' in another tale.

Hawks.—The male chicken-hawk (*i'ntlāk*, Accipiter Cooperi) is a very important character in these tales. He is the companion of the coyote in the search for the sun; in a fit of anger he throws the coyote into the fire. He is the hero of the deluge, which is indirectly caused by the infidelity of his wife, *sukpē'kā*, whom, in one version of the story, he kills. Associated with him, sometimes, is a young hawk (*gī'ākā'tlāk*). His wife is a small grey bird called *sukpē'kā*. It was her amours with the giant *yāwō'ɛnēk* that brought on the deluge.

Magpie.—The magpie, called *ānān*, tries to pick out the eyes of the coyote while the latter is lying down apparently dead.

Owl.—The owl (*kū'pī*) is represented often as an old woman who steals children. She helps to kill the chipmunk, and is herself killed by the coyote, who helps the children she carries in a basket at her back to escape.

Snow-bird.—The snow-bird (*niskā'ɛt*) is represented as the wife of the rabbit, whom she helps to kill the moose.

Tomtit.—The tomtit (*mitskā'kas*) is the grandson of the frog; after killing the caribou he is killed by the wolf. In another tale he induces the moose to come across the river to him, and then kills him with a knife.

Fish.

Trout.—In one of the tales the coyote changes himself into a trout (*g'ū'stēt*), and is caught by the Indians, who are about to hit him on the head with a club, when he calls out that he is the coyote, and not a fish; whereupon they laugh much and let him go.

Whale, or Big Fish.—The big fish (*gūwi'tlkā gā'kqō*) swallows the black bear. He is finally killed by the bird called *yāmä'kpātl*.

Insects.

Butterfly.—In one of the tales the coyote tries to run off with the butterfly (*kōlī'lā*), thinking it to be a woman. The butterfly, however, turns out to be a man, and the coyote is ridiculed.

Cricket.—The cricket (*āqkō'ktlākō'wōm*) is represented as the younger brother of the coyote, who carries him about with him, and is at times advised by him. He is sometimes mentioned as having a broken leg, and in one story the coyote breaks his own leg so as to be like his brother. The cricket seeks to kill the coyote, but is at last killed by him.

Mosquito.—There was originally one mosquito (*gātstsā'tlā*), who was fed with blood by the spirits until his belly became so large that it burst, and from it came forth the myriads of mosquitoes that exist to-day.

Reptiles.

Frog.—The frog (*wɛ'tāk*) is the grandmother of the chipmunk. In one tale he takes to wife two of the children of the grouse (*t'ā'nkūts*). The most interesting exploit of the frog is the race with the deer. The method of procedure is the same as that by which the tortoise wins in the 'Uncle Remus' story. The frogs, in large numbers, are stationed in hiding at various points in the track, and when the deer approaches them, hop on ahead, so that the deer always sees the frog ahead of him. They look so much alike that he never suspects the trick, and consequently the frog wins the race.

Toad.—The toad (*k'ō'kō*) appears in a tale with the eagle, and is killed by the chicken-hawk.

Turtle.—The mud-turtle (*kā'qā*) appears in a tale with the beaver chief, whom he kills by cutting off his head. He is afterwards thrown into the river, and escapes.

Other characters appearing in these tales are Indians, white men, giants, spirits, the heavenly bodies, &c.

Most of the tales are old, and in but two or three the white man appears, and in these he is represented as doing something ridiculous or obscene.

The Indians and the animals are so confused at times that it is impossible to say where the human and where the animal character predominates. Old men and women appear very often.

The spirits, who appear with great frequency, are represented as giving advice, being consulted by, or interfering with the actions of, the various characters. In one tale a mountain spirit is represented as harassing the Indians very much, depriving them of game, and killing the hunters who ventured up the mountain. He is finally outwitted by the coyote.

There are several giants, the principal being the monster *yāwō'ENēk*, who is represented sometimes as human, sometimes as a fish, and sometimes as a huge lake animal. He is shot by the chicken-hawk for outraging his wife, and this brings on the deluge. One of the giant tales is as follows:—A woman was out picking berries, and her child was lying on the ground near her. A giant (*ē'kā*) came along, and said to her, 'How is it that you have made my brother (*i.e.*, the child) so white and smooth?' 'Oh! I roasted him,' said the woman. Then said the giant, 'Roast me too; I want to be white and smooth.' So she set the giant to work to dig a big hole, put plenty of wood into it, and lay stones on top. On this grass was placed, and the giant lay down, and the woman piled grass, earth, and stones on him, so that in spite of his efforts he could not rise, and was roasted to death. The woman then went home, saying to her people, 'I have killed the giant.'

As mentioned above, the moon and the stars (*ā'qkitlnō'hōs*) are represented as occasionally visiting the earth. In one tale the star kills the eagle, who is found sitting on the branch of a tree.

Two very interesting tales are those of 'Seven Heads' and 'Lame Knee.' The first tale in abstract is this:—There was a young man, and his name was 'Bad Clothes' (*Sā'nūk'dlā'ENt*), and he determined to find 'Seven Heads' (*Wistādlā'dlām*) and kill him. After searching for some time he met him, and the two fought, and 'Seven Heads' was slain. The youth returned home in triumph, carrying with him the tongues of the monster as a trophy.

The outline of the story of 'Lame Knee' is as follows:—*Kō'mātlk'a'nkō*, or 'Lame Knee,' runs off with the wife of a chief and outrages her. The chief pursues, and, overtaking 'Lame Knee,' cuts off his head with a knife and throws it away, but as it rolls along the ground the head appears to laugh very much. He then cuts off one arm at the shoulder, and afterwards the other; and also the two legs are cut off one after the other. Only the trunk of the body is left, and this the chief gashes all over with his knife. At night singing is heard, and 'Lame Knee,' having risen to life again, kills the chief and departs, taking the latter's wives with him.

Regarding the relations of Kootenay mythology to the mythologies of other Indian tribes, not much can at present be said. The coyote myths seem to point to the mythic cyclus of the Indians to the south-east, from the Nez Percés to the Navajos; the Deluge legend has an Algonkian aspect; and some of the other legends point to the Sioux, and the tribes of Western British Columbia. But more study is necessary to make out definitely any points of contact.

I might here add a note on bird-cries. The Kootenays claim to interpret the following:—

Owl says: *kā'tskāki'tl pā'tlkē*; or, *ktsē'tlkenētl pā'tlkē*.

The bird called *yi'kitsnā* calls out: *iskē'tlō kā'nōqyū'qɑō*='no more buckskin horses.'

The tomtit says: *tlō'maiyēt! tlō'maiyēt!* = 'spring! spring! (No more snow! no more snow!).' The Indians like this bird very much.

The robin says: *ōkwā'nūktē'tlamtcī'yā!* = 'by-and-by plenty of rain!'

SIGN LANGUAGE.

Sign language is still in use to a considerable extent amongst the Upper and Lower Kootenays. The writer was able to obtain the following, known to members of both tribes:—

1. *Across.*—Same as first sign, described under 'Across,' in Clark's 'Indian Sign Language' (1885), p. 24.

2. *Afraid.*—Hands extended in front of body, back of hand outwards, index finger extended, rest of hand closed; the hands, which approach quite close to each other, are withdrawn with a downward movement to a distance, and in a degree corresponding to the fear to be expressed (*see* Clark, p. 25).

3. *All.*—Right hand held in front of breast, palm downwards, moved around horizontally. Same as Shushwap sign for 'all' (*see* 'Report,' 1890, p. 639).

4. *Angry.*—Right hand closed, moved rapidly before and close to forehead, keeping back of hand always to right (*see* Clark, p. 31).

5. *Axe.*—Left forearm extended in front of left side of body, hand bent at wrist and fingers inclined downwards; then right hand with thumb and forefinger (rest of hand generally closed) seizes left hand just above wrist (*see* Clark, p. 56). Downward motion of hand to imitate chopping.

6. *Bad.*—Same as sign described by Clark, p. 58, except that the downward motion is not very marked.

7. *Bark.*—Index of left hand held up stiffly, rest of hand closed or fingers drooping; right hand, limp, is then passed around index finger of left. The idea is 'stick-around' (*see* Clark, under 'Grass' and 'Tree,' pp. 192, 383).

8. *Basket.*—Elbows resting against sides of body, bring points of fingers together, so as to form rude half-circle (*see* Clark, under 'Kettle,' p. 227; 'Basket,' p. 62).

9. *Beads.*—Bring right forearm horizontally in front of body above breast, thumb touching index near the end of the latter; pass hand to and fro across neck, other fingers drooping. Compare Clark, p. 63.

10. *Bear* (*Grizzly*).—Close the hands (or sometimes let the fingers droop) and hold them close to side of head, near ears, with backs towards head. Sometimes the hands are shaken or moved about slightly, to indicate better the 'ears,' which are the basis of the sign. Clark says a similar sign is used by the Crows (p. 63).

11. *Bear* (*Black*).—Same sign as for grizzly bear, with the addition of raising hands, with thumb and index placed together, to the level of the eyes, and pointing to the outer corners of the latter. The conception 'small eyes' is at the base of this sign.

12. *Beaver.*—Same as Shushwap sign described by Dr. Boas in

'Report,' 1890, p. 639, with the addition that the right hand is given an up-and-down motion to imitate the movement of the animal's tail.

13. *Bell.*—Right hand, with fingers drooping, brought close in front of neck and given a wagging motion.

14. *Belt.*—Bring the hands (flat) together at middle of waist, then move them gradually backwards across body.

15. *Berries.*—Same as sign described by Clark under 'Rosebud,' p. 321. Sometimes, however, the sign for 'small' is made with right hand, by bringing thumb and index of right hand together a short distance from end of index; then the motion of picking something off the back of the left hand is gone through.

16. *Bird.*—Crook arms at elbows, hold hands up with palms turned somewhat outward, and give hand an upward and downward motion, fingers drooping, gradually increasing the elevation of the hands.

17. *Black.*—Touch hair with right hand, and rub back of left hand with right hand.

18. *Blanket.*—Same as sign described by Clark, p. 73.

19. *Blind.*—Shut eyes, bend the head slightly, and with hands closed, backs turned upwards, touch the eyes with the thumb and forefinger of each hand.

20. *Blood.*—Hold hands together (forefingers parallel, other fingers and thumb drooping) near mouth; make slight motion of hands forwards and upwards (*see* Clark, p. 74).

21. *Boat.*—Both hands brought close together in front of body, and then moved alternately to right and to left and downwards.

22. *Bone.*—Rub with forefinger of right hand the left hand at bony part of wrist.

23. *Bow and arrows.*—Left hand extended in front of body, palm towards breast, then pass right hand backwards over left, for motion of drawing arrow and shooting. Compare Clark, p. 76.

24. *Bread.*—Hold hands, fingers closed, palms up, in front of body, then alternately move hands together and open and shut them.

25. *Break.*—Same as sign described by Clark, p. 81.

26. *Bullet.*—Hands extended in front of body, fingers and thumb drooping, forefingers held parallel; then right forefinger is made to touch left forefinger, and to pass quickly forward, touching its whole length.

27. *Colour.*—Same as sign for 'black.'

28. *Come.*—Same as sign described by Clark, p. 122.

29. *Come here.*—Raise right hand, palm down, above head, give hand an up-and-down motion, and then move it backwards more or less quickly.

30. *Deaf.*—Press both ears with palms of hands, then raise them a little and move them to and fro over ears.

31. *Drink.*—Same as sign described by Clark, p. 156.

32. *Dumb.*—Place right forefinger or palm of right hand on lips.

33. *Evacuate the bowels.*—Assume stooping position, pass right hand, index extended, rapidly across region of buttocks in the direction of the ground.

34. *Fish.*—Same sign as described by Dr. Boas for the Shushwaps, 'Report,' 1890, p. 640.

35. *Fly.*—*See* 'Bird.' Same sign used for both.

36. *Great, large.*—Hold the arms extended at full length, fingers stretched in front of body, so as to give idea of large half-circle.

37. *Hungry.*—Touch or rub abdomen; or open mouth and move fingers of right hand, so that the ends, fingers drooping, are just within the mouth.

38. *Lake.*—Same as Shushwap sign, described in 'Report,' 1890, p. 640.

39. *Length.*—Extend the left arm in front of body, and with index finger of right hand mark off on the left arm, beginning with the ends of the fingers for small objects, portions corresponding to the distance meant.

40. *Mountain.*—Same as sign given by Clark, p. 262. *Rocky Mountains.*—Same action performed with both hands at once.

41. *Night.*—Same as sign for 'nightfall' amongst the Shushwaps. 'Report,' 1890, p. 640.

42. *Paddle.*—*See* 'Boat.'

43 *Red.*—Move right hand, palm inwards, towards cheek, rub cheek with ends of fingers. This sign arose from the *red* paint used by the Kootenays. Another sign is to touch the tongue with the forefinger of the right hand, to which is added sometimes the sign for 'colour.'

44. *Ride.*—Same as sign for 'rider' with Shushwaps. 'Report,' 1890, p. 640.

45. *Rock.*—Same as Shushwap sign. 'Report,' 1890, p. 640.

46. *Sleep.*—Bring the hands, palms inwards, close to sides of head, close eyes, and incline head towards the left and slightly downwards, so as to appear resting on palm of left hand.

47. *Small.*—Extend right hand in front of body, press second, third, and fourth fingers against palm; extend index finger, and place thumb against it a short distance from the end.

48. *Snake.*—Stretch out right hand in front of body, palm inwards; press thumb, second, third, and fourth fingers against palm, extend index, and with it make sinuous motion to imitate movement of snake.

49. *Sunrise.*—Same as Shushwap sign. 'Report,' 1890, p. 640.

50. *Sunset.*—Reverse of sign for 'sunrise.'

51. *Water.*—Same as sign for 'drink.'

Following are a few of the signs used to denote individuals of various Indian tribes:—

Flatheads.—Palms of hands, fingers pointing upwards, pressed against sides of head.

Pend d'Oreille.—Sign for 'boat' or 'paddling.'

Nez Percés.—Index finger of right hand pressed against cartilage of nose, to give the idea of 'pierced nose.'

Shoshoni, or Snake Indians.—Sign for 'snake.'

III. PHYSICAL CHARACTERISTICS.

The Kootenay Indians are physically well developed, and between the various groups there appear to be no well-marked differences. Their stature places them amongst the tallest tribes of British Columbia, nine out of thirty-six adult males, or one-fourth, having a height of more than 1,739 millimetres, and one individual actually measuring 1,846 millimetres, while three others were 1,767, 1,760 and 1,770 millimetres respectively. Two-thirds of the individuals measured are included between 1,660 and 1,779 millimetres, with an average approximately at 1,690. The women, if we may judge from the few cases here recorded, are much

shorter than the men: three females, aged 14, 18, 40, measured respectively 1,557, 1,570, and 1,582 millimetres. There appears to be not so great a difference between the heights of the boys and girls.

The index of finger-reach seems to be slightly less than that of the Bilqula and some other tribes, two-thirds being found between the indices 102 and 106, but nearly one-third falling below 102.

The index of height, sitting, is also lower, two-thirds having an index of from 50 to 53, and but ten cases out of thirty-five having an index of more than 53.

The index of length of arm has the largest number of cases at 45, and two-thirds of the total come within the limits 43 to 46.

The indices of height and width of shoulder are more variable. The index of height of shoulder shows the greatest grouping (ten cases out of thirty-four) at 85, and between 82 and 84 two-thirds (twenty-two cases) occur. Of the indices of width of shoulder two-thirds (twenty-one cases) are found ranging from 18 to 20.

The indices of face show a range from 77 to 93, with the greatest accumulation (nine cases out of thirty-two) at 88, and having nearly one-half (fifteen cases out of thirty-two) the number of cases with an index of between 86 and 89. The facial index of the Kootenays is therefore higher than that of the western tribes of British Columbia.

The indices of the upper part of the face have their greatest grouping at 55 (eight cases out of thirty-three), and nearly two-thirds are contained between 52 and 57, while eight cases, or nearly one-fourth, are above 57.

The nasal indices show the greatest grouping (six cases out of thirty-four) at 70, and there is none below 58.

Thus far we have dealt with adults alone. It seems allowable in the case of the cephalic index to include all individuals of five years and over. This gives us, of pure blood Kootenays, seventy males and fourteen females. Of the females, thirteen have an index of over 78 (corresponding to 76 on the skull), and eight have an index of more than 83 (81 on the skull). If one is to judge from these fourteen cases, the Kootenay women are brachycephalic; a fact which would correspond with their seemingly much shorter stature. This apparent brachycephalism may, however, be the result of the comparatively small number of individuals measured.

The cephalic indices of the males range from 72 to 86 (corresponding to 70 and 84 on the skull), with the greatest grouping at 77 (75 on the skull). Fifty-five cases are found below 80 (78 on the skull). More than half are thus mesaticephalic. It is just possible that we have here an intermixture of a brachycephalic type, but this would perhaps be sustained if several hundred measurements had been taken.

The cephalic indices of the half-breeds show considerable variation, and the females tend towards brachycephaly, as was the case with the pure Indians.

It is usually impossible to obtain the weight of aborigines owing to the lack of weighing apparatus; hence the few cases here recorded will be of considerable interest. They are presented on next page rearranged according to age:—

These measurements were taken when the Indians had a normal amount of summer clothing on.

The average weight of thirteen adults (from nineteen to fifty-nine years of age) is 151 pounds.

Name	Age	Weight in Pounds	Name	Age	Weight in Pounds
Samuīl Piel . .	2	25	Joseph . . .	20	153
André . . .	4	31	A'mɛlū . . .	22	177
Skū'kɛm Joe Nána .	5	46	Kaplō . . .	26	150
Pōl Nána . . .	5½	48¼	Pōl	28	150¼
Piel	10	64	Salwā Q . . .	31	147
Piū	14	100	Skū'kɛm Joe . .	33	156½
Baptiste . . .	15	123	Simō K. . . .	51	141¼
André . . .	16	134¼	Wilyam Q . .	51	147¼
Piel	19	142	Dominick . .	59	149½
Eustā . . .	19	177½	Blaswā . . .	60+	146
Eustace Benwīl .	19	137	Old Joe	65	135
Joseph . . .	20	134½			

The eyes of the Kootenays are dark-brown, the hair straight and black. There are, however, quite a number of cases of brown hair; but as these seem to occur with children and those adults who habitually go bareheaded, the difference in colour may be attributed to exposure to the air and sunlight. In a few cases also the hair is quite wavy, in some, even curly; and one of the Fort Steele Indians is nicknamed 'Curly' (*Kāntlū'mtlām*) from this fact. But one or two cases of the 'Mongolian eye' were observed, the Indian Gīaqkātl Sālō being one.

The colour of the skin is, in general, brown, varying from rather dark to a dirty white. Many of these Indians, as far as colour of skin is concerned, would be quite indistinguishable from the dark-skinned natives of Southern Europe. The contrast between them and the Chinese—the writer had the opportunity of seeing them very often together—is marked, and they would never be mistaken one for the other by experts.

Hair on the face and body is not common on account of the practice of removing the hairs which the Indians more or less practise. Still, beards and moustaches are possessed by some of the Indians. Kootenay Pete, an old Indian of Columbia Lakes, had a white beard, small in size, but at least 60 millimetres long; Chief Eustan, of the Lower Kootenay, had a number of white hairs on his chin; and another Indian of the same tribe, aged about sixty, had a slight beard and moustache, both whitish, and dark and heavy eyebrows; an Upper Kootenay, aged thirty-one, had also a slight beard. An Indian, named Blasois, aged seventeen, had a few hairs on his nose.

The noses seem rather flat. The shape of the nose itself varies; the largeness of the nostrils is very striking in many cases, as is also the depressed root of the nose with prominent glabella. The nose of one Indian was so perceptibly large that it formed a constant point for the merriment of his fellows, and one of the names of the Indian Patrick (*Gā'tlɛmā'kastlā'ɛkāk*) refers to his 'big nostrils.' The point of the nose is in most cases short. Straight noses with pointed ends are not unknown.

In a few cases the ears of Indians are distorted and lengthened by heavy earrings. The ears of the great majority are, however, medium-sized, most often with round and attached lobe.

The mouths of many of the Kootenays seem disproportionately large, and the lips are often very thick, as in the case of the Indian A'mɛlū, whose ears, it might be remarked, were rather small.

The teeth of these Indians are remarkably well preserved, the writer

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III. Masai Ugogo and Usukuma. IV. Mkesi Kootenay. V. Mdio, Upper Kootenay. VI. Mdio, Upper Kootenay. VII. Mdio, Lower Kootenay. VIII. Mdio, Lower Kootenay.

	Males		Males		Male	Females			Males			Females			
No.	1	2	1	2	1	1	2	3	1	2	3	1	2	3	4
	Height	Height of Eye (Tragus)	Ht.	Arch. Height	Head Length	Ht.	Nose Length	Nose Breadth	Jaw Length (Gonion to Pt. of Chin)	Jaw Width (Gonion to Gonion)	Jaw Angle (Gonion to Gonion)	Face Width (Zygomatic Arch)	Face Height (Nasion to Gnathion)	Arch Height	Arch Length
	E. Upper Kootenay W. Upper Kootenay	I. Upper Kootenay Lower Kootenay Mdio, Lower Kootenay Upper Kootenay	M. Lower Kootenay	F. Upper Kootenay W. Masai	F. Mdio, Upper Kootenay Upper Kootenay Mdio, Lower Kootenay Lower Kootenay	E. Mdio W. Masai, Upper Kootenay			F. Mdio, Upper Kootenay W. Masai, Upper Kootenay		N. Mdio, Lower Kootenay	F. Mdio, Lower Kootenay			
Age	26	59	20	22	8	7	9	19	2	14	27	4	5	9	14
	inch.	inch.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height, standing	1,745	1,680	1,614	1,702	1,228	1,208	1,260	1,053	705	1,675	1,693	1,094	1,1	1,[illegible]	1,[illegible]
Height of shoulder	1,436	1,420	1,392	1,441	970	972	1,038	1,405	—	—	1,445	855	900	1,142	1,[illegible]
Height of point of second finger	668	615	638	622	460	431	441	649	—	—	652	374	395	612	622
Length of arm	768	805	734	819	550	541	597	766	—	—	783	481	575	1,[illegible]	7,[illegible]
Extension reach	1,799	1,714	1,714	1,785	1,227	1,212	1,312	1,631	760	1,658	1,765	1,100	1,185	1,112	1,[illegible]
Sitting height	910	819	865	907	619	609	679	854	428	—	918	614	636	760	8[illegible]
Width of shoulders	375	375	392	385	256	249	265	351	151	264	317	218	245	277	3[illegible]
Length of head	1,5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17	18,[illegible]	1	187	18[illegible]	1[illegible]	15[illegible]	18[illegible]	[illegible]
Breadth of head	1,[illegible]	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]	11[illegible]	1[illegible]	1	1[illegible]	11[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Distance from root of nose to chin	1,3	1,[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]	[illegible]	1,[illegible]	1,[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]	1,[illegible]	1,[illegible]
Distance from root of nose to hair	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62	87	7[illegible]	78	84	7[illegible]	[illegible]	[illegible]	7[illegible]	[illegible]
[illegible] top															
Width across	145	148	143	164	121	120	127	131	108	135	159	121	116	119	1[illegible]
Height [illegible]	55	62	55	58	45,5	56	50	64	33	60	67	40	38	50	48
Width	43	47	43	44	[illegible]	[illegible]	37	33	26	32	35,5	25	30	31	31
Width [illegible]	1,[illegible]	1[illegible]	[illegible]	177	—	—	—	—	—	—	—				
Indices:															
Height of shoulder	82,3	84,5	81,7	84,7	80,6	80,5	82,4	85,0	—	—	84,8	78,2	81,7	80,4	82,7
Height of point of [illegible]	41,6	42,9	41,9	43,1	43,2	44,8	47,1	46,7	[illegible]	[illegible]	43,1	41,0	38,9	44,4	44,2
Height of point of [illegible]	38,1	36,6	41,2	40,8	37,5	38,1	40,1	38,7	40,4	40,0	38,5	38,5	36,9	40,5	42,5
Index of height, sitting	52,1	48,8	53,7	53,3	52,9	54,1	54,3	54,5	60,7	—	54,2	56,3	54,1	55,7	54,5
Index of width of shoulders	21,5	22,3	24,3	22,6	20,8	20,6	21,0	21,2	21,4	19,8	18,7	20,0	20,7	20,0	17,6
Cephalic index	77,2	77,6	75,6	74,5	77,1	80,8	81,5	82,4	84,9	85,7	79,2	80,4	77,1	77,5	76,6
Index of upper part of face	51,8	50,1	53,3	54,25	52,30	54,66	54,18	56,10	55,76	54,22	54,85	55,54	55,17	54,4	56,0
Nasal index	91,03	84,71	80,42	94,70	79,34	81,66	73,23	80,20	84,33	82,22	82,13	92,50	76,72	86,66	90,2[illegible]
Orbital index	78,17	74,58	78,17	79,86	67,31	71,73	74,00	76,14	78,78	87,14	82,28	80,08	78,95	82,00	81,[illegible]

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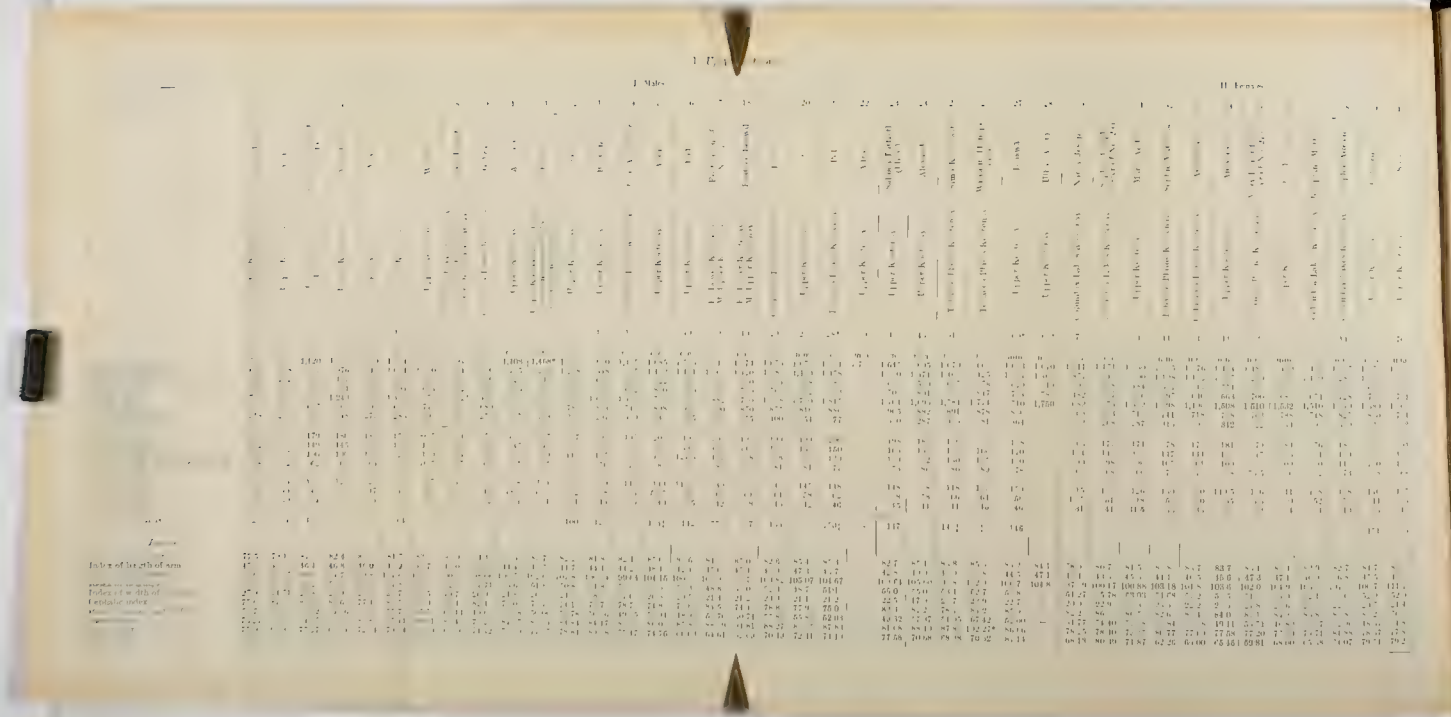
Tribe	No.	Height, standing	Height of shoulder	Height of finger-reach	Length of head	Breadth of head	Distance from root of nose to chin	Distance from root of nose to between lips	Weight in pounds	Indices: Height of shoulder	Index of length of arm	Index of finger-reach	Index of height, sitting	Index of width of shoulders	Cephalic index	Index of upper part of face	Facial index	Nasal index
Lower Kootenay	1	1,400	1,166	1,178	189	142	111	76	130	833	44·1	101·0	60·5	22·8	79·3	61·90	87·4	44·8
Lower Kootenay	2	1,661	1,371	1,411	182	141	111	76	130	825	46·1	104·1	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	3	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	4	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	5	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	6	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	7	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	8	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	9	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	10	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	11	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	12	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	13	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	14	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	15	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	16	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	17	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	18	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	19	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	20	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	21	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	22	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	23	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	24	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	25	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	26	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	27	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	28	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	29	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	30	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	31	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	32	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	33	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	34	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	35	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	36	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	37	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	38	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	39	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	40	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	41	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	42	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	43	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	44	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	45	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	46	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	47	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	48	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	49	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	50	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	51	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	52	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	53	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	54	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	55	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	56	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	57	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	58	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	59	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	60	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	61	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	62	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	63	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	64	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	65	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	66	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	67	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	68	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	69	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	70	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	71	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	72	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	73	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	74	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	75	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	76	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	77	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	78	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	79	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	80	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	81	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	82	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	83	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	84	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	85	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	86	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	87	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	88	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	89	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	90	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	91	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	92	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	93	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	94	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	95	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	96	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	97	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	98	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	99	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1
Lower Kootenay	100	1,677	1,411	1,411	184	142	111	76	130	841	46·1	100·0	58·0	19·6	77·5	67·14	87·1	47·1

NATIONAL HISTORY.



having seen but a single case of caries, and that in a boy. The chins are, as a rule, well formed, both in men and women. The foreheads appear to be broad and straight. In the case of an Indian (André) aged sixteen the distance from chin to the hair-line was 187 millimetres. The glabella is generally 3 to 4 of Broca. The superciliary ridges are quite prominent in many cases. The faces seem broader than they really are, and the cheekbones often prominent. The limbs appear to be well-shapen, but in not a few cases the hands are rather large, the shoulders stooped, or the legs bandy.

To distinguish a Kootenay from an Indian of some other tribe may be at times difficult: mix one Shushwap amongst a few dozen Kootenays, or *vice versâ*, and he may remain perhaps undetected; but arrange twenty Kootenays in a line facing twenty Shushwaps or twenty Stonies, and the great difference that really exists between them will flash on the observer in a moment, and if another Shushwap or a Kootenay happens to come along he will unhesitatingly be assigned to his proper place. The writer had no difficulty in picking out two Crees from a number of Blackfeet, who were in a line opposite a number of Kootenays. The *ensemble* of the Blackfeet was broken by the presence of these two Crees, and the conviction that they were not Blackfeet came at once. Many of the mistaken theories of Indian origins and of the exact resemblances of far distant tribes may arise from the fact that the observer who relates his experiences has never seen, say, a hundred individuals of each tribe drawn up in line opposite each other, and been able to get, as it were, a mental composite photograph of each ethnic group. When twenty Chinamen and twenty Kootenays are placed opposite each other in like manner, no one would for a moment judge them to be the same, or even similar.

The tables opposite contain measurements of forty Upper Kootenays, forty-nine Lower Kootenays, four Kootenay Métis, eleven Kootenay-white Métis, making a total of 104 individuals, of ages ranging from two to seventy years, and coming from all parts of the Kootenay country.

The measurements were taken in a manner similar to that described by Dr. Boas in 'Report,' 1891, p. 425, and the indices calculated in like manner. Very few females could be measured on account of the prejudices of the Indians.

The measurements were as follows:—

Height, standing.
,, of acromion.
,, ,, point of second finger.
Finger-reach.
Height, sitting.
Width between acromia.
Length of head.
Breadth of head.
Distance from naso-frontal suture to chin (height of face).
Distance from naso-frontal suture to between the lips (height of upper part of face).
Width between zygomatic arches (width of face).
Height of nose.
Width of nose.

The length of the arm is obtained by subtracting the height of the point of second finger from the height of the acromion. The weight, which was obtainable in but few cases, is given to quarters of a pound, from an excellent scale in the store of Mr. Galbraith.

The ages, especially of the Upper Kootenays, may be relied upon as being as nearly correct as possible, the margin of doubt being very small.

The tribes of the father and mother are given, where such could be ascertained, and the relationship of the various individuals is indicated.

The following tables exhibit in a more condensed form the measurements contained in the preceding pages, and need no special explanation:

Stature, Kootenay Males (19–51 *years*).

Tribes	Centimetres													Number of Cases
	160 161	162 163	164 165	166 167	168 169	170 171	172 173	174 175	176 177	178 179	180 181	182 183	184 185	
Lower Kootenay	2	1	2	1	4	4	4	3	3	—	—	—	—	24
Upper Kootenay	1	—	1	5	—	—	2	—	1	—	—	—	1	11
Mixed Upper and Lower Kootenay	—	—	—	—	—	—	—	1	·	—	—	—	—	1
Total	3	1	3	6	4	4	6	4	4	—	—	—	1	36

Index of Finger-reach, Males (19–51 *years*).

Tribes	Percent. of Stature															Number of Cases
	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	
Lower Kootenay	—	—	1	3	3	3	3	3	1	4	1	—	—	—	—	22
Upper Kootenay	—	—	—	1	2	1	2	1	2	1	—	—	—	—	—	10
Mixed Upper and Lower Kootenay	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
Total	—	—	1	4	5	4	6	4	3	5	1	—	—	—	—	33

Index of Height, sitting.

Tribes	Percent. of Stature														Number of Cases
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	
Upper Kootenay	—	2	—	—	2	3	2	—	2	—	—	—	—	—	11
Lower Kootenay	—	—	—	3	2	5	5	3	3	—	2	—	—	—	23
Mixed Lower and Upper Kootenay	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
Total	—	2	—	3	4	9	7	3	5	—	2	—	—	—	35

Index of Height of Shoulder.

Tribes	Percent. of Stature													Number of Cases
	77	78	79	80	81	82	83	84	85	86	87	88	89	
Lower Kootenay	—	—	1	—	—	3	6	7	5	—	—	—	1	23
Upper Kootenay	—	—	—	—	—	2	2	1	5	—	—	—	—	10
Mixed Upper and Lower Kootenay	—	—	—	—	—	1	—	—	—	—	—	—	—	1
Total	—	—	1	—	—	6	8	8	10	—	—	—	1	34

Index of Width of Shoulders.

Tribes	Percent. of Stature										Number of Cases
	16	17	18	19	20	21	22	23	24	25	
Lower Kootenay	—	—	8	8	4	1	—	1	—	—	22
Upper Kootenay	—	1	—	—	1	5	2	1	—	—	10
Mixed Lower and Upper Kootenay	—	—	—	—	—	1	—	—	—	—	1
Total	—	1	8	8	5	7	2	2	—	—	33

Index of Length of Arm.

Tribes	Percent. of Stature										Number of Cases
	40	41	42	43	44	45	46	47	48	49	50	
Lower Kootenay	1	—	2	4	4	3	5	2	—	1	—	22
Upper Kootenay	—	—	2	1	—	4	—	1	—	1	1	10
Mixed Upper and Lower Kootenay	—	—	—	—	1	—	—	—	—	—	—	1
Total	1	—	4	5	5	7	5	3	—	2	1	33

Cephalic Indices (Males over 5 years).

Tribes	Indices															Number of Cases
	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Lower Kootenay	2	2	1	3	6	6	5	4	2	3	2	3	1	2	2	44
Upper Kootenay	—	—	3	3	—	2	3	3	2	—	3	2	2	1	—	24
Mixed Upper and Lower Kootenay	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	2
Total	2	2	4	6	7	9	8	7	4	3	5	5	3	3	2	70

Cephalic Indices (Females over 5 years).

Tribes	Indices															Number of Cases
	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Lower Kootenay	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	2
Upper Kootenay	—	—	—	—	1	—	—	—	—	1	3	—	2	5	—	12
Total	—	—	—	—	1	—	—	1	—	1	3	—	2	6	—	14

Cephalic Indices (Métis, Kootenay and Whites, Males over 5 years).

Tribes	Indices															Number of Cases
	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Lower Kootenay Métis	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	2
Upper Kootenay Métis	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
Total . .	—	—	—	—	1	1	—	—	—	—	1	—	—	—	—	3

Cephalic Indices (Métis, Kootenay and Whites, Females over 5 years).

Tribes	Indices																	Number of Cases
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Lower Kootenay Métis	1	—	—	1	—	—	—	1	—	—	1	—	—	—	—	—	—	4
Upper Kootenay Métis	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	—	—	3
Total .	1	—	—	1	—	—	—	1	—	—	2	—	1	—	1	—	—	7

Index of Upper Part of Face (Males, 19–51 years).

Tribes	Indices																					Number of Cases
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	
Lower Kootenay	—	—	—	1	1	2	3	2	5	2	—	2	1	2	1	—	—	—	—	—	—	22
Upper Kootenay	—	1	1	—	—	1	—	1	3	—	1	—	—	1	—	—	—	—	—	1	—	10
Mixed Lower and Upper Kootenay .	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Total	—	1	1	1	1	3	3	4	8	2	1	2	1	3	1	—	—	—	—	1	—	33

Index of Face (Males 19–51 years).

Tribes	Indices																					Number of Cases
	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95		
Lower Kootenay	—	2	—	—	1	1	2	2	2	—	3	—	6	—	—	1	1	1	—	—		22
Upper Kootenay	—	—	—	—	—	1	—	—	1	—	1	1	3	1	—	—	—	1	—	—		9
Mixed Upper and Lower Kootenay. .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—		1
Total	—	2	—	—	1	2	2	2	3	—	4	1	9	1	—	2	1	2	—	—		32

Index of Nose (*Males*, 19–51 *years*).

Tribes	Indices																									Number of Cases
	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	
Lower Kootenay .	—	2	—	—	1	1	3	2	1	1	—	1	3	2	2	1	—	—	—	—	1	—	1	—	—	—	1	23
Upper Kootenay .	—	—	—	—	1	—	1	—	1	—	1	—	3	—	1	—	1	—	—	1	—	—	—	—	—	—	—	10
Mixed Upper and Lower Kootenay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
Total . .	—	2	—	—	2	1	4	2	2	1	1	1	6	2	3	1	1	—	—	1	2	—	1	—	—	—	1	34

IV. LINGUISTICS.

The Kootenay, spoken in two slightly differing dialects, the Upper Kootenay and the Lower Kootenay, forms a linguistic stock by itself. The writer's examination of the material he obtained does not lead him to expect any serious modification of this position. No traces of connection with, or relation to, the Blackfoot tongue were discovered, and except a seeming similarity in a few points of general structure to the Shoshonian and to the Siouan tongues, no points of resemblance except of the vaguest and pan-American kind have been found with the neighbouring languages.

The Kootenay is incorporative (both as regards the pronoun- and the noun-object), abounds in prefixes and suffixes, both in the verb and in the noun, has certain inflections of adverbs, nouns, and pronouns by suffixes, and possesses an elaboration of structure which the writer hopes to be able to explain and illustrate after a more thorough study of the linguistic material in his possession. The incorporation of the object-noun in the verb is characteristic of Shoshonian tongues, but the Kootenay is remarkably free from forms by reduplication, and so marks itself off from these languages in which that peculiarity is highly developed.

The few details that the writer has been able to work out will be found in the following pages.

As examples of the exceedingly composite character of the Kootenay language, a noun and a verb analysed into their component elements may be given here:—

Crown of head = *āqki'nk·ānū'ktlā'mnam* = *āqki'nk·an* (top) + *ūk* (point) + *tlām* (head) + *nam* (= somebody's). *Aqkink·ā'n* is further to be decomposed into *āq* + *kin* + *k·ān*, the last being probably the radical for 'top.'

He is going to bite us = *tsqātli'tqanāwa'sinē* = *ts* + *qātl* (prefixes of future tense) + *itqa*(*n*) [to bite = *it*, to do + *qa*(*n*), with the teeth] + *-n-* (verbal ?) + *āwas* (= he . . . us) + *ī* (verbal) + *nē* (verbal).

Phonetics.

The Kootenay language possesses the following vowel sounds:—

a as in German M*a*nn.		*ī* as in English p*i*que.	
ā as in English f*a*ther.		*o* „ „ b*o*nd.	
â „ „ *a*ll.		*ō* „ „ b*o*ne.	
ä „ „ *a*m.		*u* „ „ w*oo*d.	
e „ „ p*e*n.		*ū* „ „ b*oo*t.	
ē „ „ th*ey*.		*ai* „ „ *ai*sle.	
ë „ „ fr*e*sh (exaggerated).		*au* „ „ br*ow*n.	
ɤ „ „ flow*e*r.		*ʌɪ* „ „ b*oi*l.	
i „ „ p*i*n.		*ɛɪ* as in French faut*euil*.	

There is a frequent interchange of vowels in Kootenay, the chief equivalents being as follows:—

E = a, ā, ä, ē, e, ū, o, ō, i.
I = i = e = ē.
ō = ū (very common).
i = ō, ū, o, u, a.

The consonantal sounds of the Kootenay are:—

d, *t*, as in English. Often pronounced, however, more forcibly as *t'*, *d'*.

g, *k*, as in English. Often pronounced, however, more forcibly as *g'*, *k'*.

*g*ˑ, *k*ˑ, very guttural *g* and *k*, written by some authorities *gr* and *kr*. Uttered more forcibly as *g*ˑ', *k*ˑ'.

gy, *ky*; *q*, German *ch* in *Bach*; ᴏ approximately the same sound, but slightly less guttural; ʜ, German *ch* in *ich*; *h* as in English; *y* as in English; *p* (uttered more forcibly as *p'*), *m*, *w*; *n*; *s* as in English; *c* = English *sh*; *ts*; *tc* = English *ch* in *church*; *dj* = English *j*; *tl*, explosive *l*, *dl* (dorso-apical); *l*.

The chief consonantal equivalents are:—

q = ᴏ = ʜ = *h*; ts = tc = s = c;
tl = *dl*; *d* = *t*; gˑ = g; kˑ = k.

The Kootenays can pronounce some of the letters which are not in their own language. The following lists, the one of French proper names bestowed on the Kootenays and their phonology as given by them, the other of English words, which the writer had the Indians pronounce after him time and time again in order to be sure of the phonetics, may be of some value:—

I.

French	Kootenay	French	Kootenay
Pierre	*Pīel.*	Fabien	*Bä'bīĕn'.*
Joseph	*Sōsep.*	Adrien	*Atlīĕ'n.*
Gabriel	*Käplīe'l.*	Urban	*Ulbā(n).*
Sophie	*Sōpī.*	Marie	*Mālī.*
Paris	*Pālīs.*	St. Pierre	*Säpīèl.*
François	*Bläswā.*	Antoine	*Atōwā'(n).*
St. Louis	*Säl'wā.*	Patrick	*Pätlik.*
Nicholas	*Nīkwā'la.*		

II.

English	Kootenay's rendering	English	Kootenay's rendering
bacon	*pē'kᴇn.*	Johnnie	*Tco'nī.*
Bob	*Bōp.*	log	*lo'k.*
Bonner's Ferry	*Bᴇ'mᴇs Fä'lī.*	lumber	*lᴇ'mbᴇ.*
bread	*bled.*	mission	*mi'sᴇn.*
buffalo	*bu'palō.*	mush (*i.e.*, porridge)	*mᴇs.*
caribou	*kä'lībū.*	Nelson	*No'lsᴇn.*
chipmunk	*tci'tmᴇf.*	nine	*nāi'.*
cigarette	*siglä't.*	owl	*ā'ūᴇl.*
coffee	*ko'pī.*	pepper	*pe'pᴇn.*
corn	*k'ā'ᴇn.*	père (Fr.)	*päl.*
crackers	*tlä'kas.*	pocket	*pä'kᴇt.*
croak	*tlōk.*	potato	*pᴇtē'tᴇ.*
damn	*täm.*	rain	*lēn.*
den	*dän.*	rapid	*lä'pit.*
deer	*dī'ᴇ.*	rice	*lais.*
eleven	*le'bᴇn.*	ride	*laid.*
ferry	*tā'lī.*	river	*li'bᴇ.*
fire	*pā'iᴇ*; *fā'iᴇ.*	rock	*lok.*
fish	*pis*; *fis.*	run	*lᴇn.*
five	*fāi.*	Rykert	*la'ikᴇt.*
flour	*plā'uᴇ.*	salt	*sā'ᴇl.*
fly	*plāi.*	Sand Point	*Sän Pō'ī.*
fork	*fâk'.*	seven	*se'bᴇn.*
Fort Steele	*Fo'tᴇ Stīl.*	six	*sik.*
frog	*flok.*	skunk	*skᴇnˑk* (no *g* sound).
good	*gūt.*	sleep	*sīp.*
grass	*gläs.*	snore	*snō'ᴇl.*
hiss	*hës.*	spring	*splin.*
hit	*hët.*	store	*stō'ᴇl*
horse	*hä'ᴇs.*	straight	*trēt.*

English	Kootenay's rendering	English	Kootenay's rendering
sugar	*sw'kɛn.*	trail	*fēl ; tvēl.*
tamarack	*tä'mlok.*	tree	*tlī.*
thick	*fik.*	twelve	*twël.*
thin	*fin.*	weasel	*wi'zɛl.*
three	*trī.*	whistle	*wi'sɛl.*
tired	*tait.*	wild	*wail.*

The most interesting points brought out in the pronunciation of these words are :
French : *r=l ; f (ph)=p ; j=s ; f=b.*
English : *r=l ; f=p ; b=p ; d=t ; cr=tl ; sh=s ; g=k ; r=n ; th=f ;* and amongst the vowel sounds English *i=ë.*
We have also Kootenay *tlī'kapō'=līkapō'* (French, *le capot*).
In this report the accent is marked thus, ', the sign immediately following the syllable accented.

Grammar.

NOUN. GENDER.

Grammatical gender does not exist in Kootenay. Some words are used of males and females alike, with no change of form, *e.g.* :—

tlū tlūmā'tl = widow ; widower.
nā'nkā = orphan (boy or girl).
tlkā'mū = infant (boy or girl).

Gender is distinguished in the following ways :—

1. By the use of entirely different words for the male and female :—

Buffalo bull, *ni'tltsik.* Elk (male), *k'i'tlk·ā'tlē.*
„ cow, *tlū'kpū.* „ (female), *tlā'wū.*

2. By suffixing or (rarely) prefixing *kɛ'skō* (male) and *stō'kwātl* (female) :—

Duck (male), mallard, *ka'nk·ūskō'ik·āk kɛ'skō.*
„ (female), „ *stō'kwātl.*
Horse, *k'ā'tlaqā'ɛtltsin kɛ'skō.*
Mare, „ *stō'kwātl.*

3. Where no ambiguity is liable to occur, the terms *kɛ'skō* = 'male, boy, horse, dog,' &c., and *stō'kwātl* = 'girl, female, mare, bitch,' &c., are employed without the class-noun.

NOUN. DECLENSION.

The Kootenay noun has an indefinite form in *-nām* (*-näm*, *-nam*) thus :—

titō'nām, father (of a man).
sō'nām, father (of a woman).
āqkātlā'nām, a house.

This *-nām* does not appear in all words, and some of the Indians never use it with the word *wātlū'nāk* (tongue), for example, while others do. It may be that its use was formerly more extensive than at present, as the existence of the Lower Kootenay *pādlkē'nām* (woman), *titk'ā'tɛnām* (man), seems to indicate.
The uses of a definite article or demonstrative adjective are in some way served by the particle *tcin* or *tsɛn*. Thus :—

tcin ni'tlkō = iron, *i.e.*, *the* metal.
tsɛn āqkts'mā'kinik = Indians, *i.e.*, *the* men.

The substantive seems to have an uninflected and an inflected form, which apparently can be used interchangeably. (The initials U.K. and L.K. stand for Upper and Lower Kootenay.)

Uninflected Form.

Indefinite form: *pā'tlkē* (U.K.); *pādlkē'nām* (L.K.).
Singular: Nominative, *pā'tlkē*.
Objective and oblique cases, *pā'tlkē*.
Dual: Nominative, *ä'snē pā'tlkē*.
Objective, &c., *ä'snē pā'tlkē*.
Plural: Nominative, *pā'tlkē*.
Objective, &c., *pā'tlkē*.

All nouns may be treated in this way, and then the form for singular and plural remains the same.

There exists also a declension which is as follows:—

Indefinite form: *pā'tlkē*; *pādlkē'nām*.
Singular: Nominative, *pā'tlkē*.
Objective, &c., *pā'tlkēs*.
Dual: Nominative, *pā'tlkēki'stik*.
Objective, &c., *pā'tlkēkistik(ē)s*.
Collective: Nominative, *pā'tlkēki'ntik*.
Objective, &c., *pā'tlkēkintik(ē)s*.
Plural: Nominative, *pā'tlkēni'ntik*.
Objective, &c., *pā'tlkēnintik(ē)s*.
Distributive: Nominative, *pā'tlkēkä'ntik*.
Objective, &c., *pā'tlkēkä'ntik(ē)s*.

The Kootenay seems to possess, therefore, a case-inflection in *-s* or *-es*, a plural in *-ni'ntik*, a collective in *-ki'ntik*, a dual in *-ki'stik*, a distributive in *-kä'ntik*. The following examples will serve as illustrations:—

ō'pqanē āqkinmi'tūks ski'nkūts, the coyote sees the river.
ō'pqanē nā'k'yū yā'wōs wū'ōs, he sees the fox down in the water.
ipi'tlnē nē'is na'qanēs, he kills (him) the caribou.
kāna'qē ski'nkūts nātlqō'nē kā'qkēns, the coyote goes along, carrying the wolf.
ō'pqanē ni'tltsiks skā'sī, he sees the buffalo bull coming.
kāna'qē ā'qkitlnō'hōs, nū'pqanē tlkā'mūs ni'ksī ä'māks, a star is going along, [and] sees a little child eating dirt.
āqkonā'nōks kā'usāk'ā'nē k'ō'tsāts, the chipmunk sits on the willows.
ta'qas kāntlā'tltē ski'nkūts tlā'utlās, the coyote struck the grizzly bear.
nā'nakisqā'mnē nē tlkā'mūki'stēk, these two children go away.
nū'pqanē yū'nā k'ä'psi tlkā'mūninte'kēs, he sees many children.
ki'nākā'sak'ā'tlkā nipi'k'āni'ntik? where are you gone, spirits?
tinaqā'mnē yū'nāk'ä'psī tlkā'mūni'ntik, many children enter.

Combined with the possessive pronouns, nouns are declined as follows:—

k'āti'tō, my father (father of man).
titō'nis, thy father.
titō'is, his father.
kāti'tōnā'tla, our father.
titōni'skētl, your father.
titōi'sis, their father.

When declined with the possessive pronouns, some nouns sometimes lose one or more of their prefixes, thus:—

āqkītlā'nām, house.
kākītlā, my house.
ā'qkītlā'sis, his house.

The word for 'horse' presents some peculiarities. The Upper Kootenay form is *k'ātlaqā'ɛtltsin*, the Lower Kootenay *g·itlk'ā'tlaqā'ɛdltsin*, the latter being the more primitive. The etymology is apparently 'elk-dog,' 'elk' in Upper Kootenay being *gitlk'ā'tlē*, and in Lower Kootenay *gi'dlk'ā'dlē*. In declension, however, the word for 'elk' drops out entirely, and we have only *qāɛtltsin* (dog) left. This does not always occur, however.

horse, *k'ā'tlaqā'ɛtltsin*.
our horse, *kāqāɛtltsinnā'tla*.
your horse, *qā'ɛtltsinni'skētl*.

The noun denoting the object possessed, or in the genitive, may precede or follow the governing noun. Thus :—

wɛ'tāk titē'is k·ō'tsātc, the frog, grandmother of the chipmunk.
gi'sin' yū'kwā titō'nis? is that the hat of your father?
enē sinā āqk·ō'tātls, it is beaver grease.

COMPOSITION.

Some compound nouns are formed by the simple juxtaposition of two substantives, thus :—

ā'qkink·ō'k·ō yāk·tsō'mētl (fire + canoe), steamboat.
k'tcitlmī'yit natā'nik (night + sun), moon.

The qualifying noun precedes.

In other cases the compound consists of radicals, prefixes, and suffixes. For example :—

kīkāntlā'tltēmō'tl (that with which striking is done), whip, from *kāntlā'tltē* 'strike,' prefix *kī-*, instrumental suffix *-mōtl*.

āqkīnū'qtlū'tlām (its head is white), white-headed eagle, from radicals *nū'qtlū*, white, *tlām*, head, and prefixes *āq-* and *kī-*.

NOUN AND VERB.

The following examples will serve to show the relation between the noun and verb as regards matters of derivation :—

Bark (of tree)	*āqkitsk·ā'tl.*
	hōtstlū'tsk·ātlqō'nē, I take the bark off a tree.
Bread (baked in pan)	*kānkū'ptcē.*
	hōtcā'nkūptcē'tē, I bake bread.
Bridge	*āqkō'kō'.*
	hō'tsitkō'kōpki'nē, I make a bridge.
Brush	*kūpkō'mātlkō'mōtl.*
	hō'tsōpk'ōmatlqō'nē, I brush.
Comb	*tcūk'tlāmāniyātl.*
	hōtcū'k'tlāmā'mēk, I comb.
Heart	*āqkī'tlwī.*
	k'ōkātlwī'nē, I think.
Peel	*tlūtlā'ɛtimō'tl.*
	hō'tlūtlā'timō'nē, I take the peel (rind) off (an apple).

DIFFERENCES OF FORM IN NOUNS WHEN USED INDEPENDENTLY, AND WHEN IN COMPOSITION.

One of the peculiarities of the Kootenay language is the existence of different forms when the word is used in composition, and when it is used independently.

—	Form in Composition	Independent Form	Examples of various Compositions
Bag .	*tlā'kō*	*ā'qkōtlā'kō*	*gīyū'nātlā'kō*, 'He has many Pockets' (a personal name).
Belly .	*(ō)wōm ; wūm*	*āqkō'nōm*	*tsɛmā'kōwōm*, 'Strong Belly.' *witlwū'mnē*, 'his belly is large.'
Clothes .	*ūk·tlā'ɛnt*	*ā'qkūk·tlā'ɛnt*	*sā'nūk·tlā'ɛnt*, 'Bad Clothes' (a personal name).
Ear .	*k·ōāt (k·ūnāt)*	*āqkō'k·ōāt (aqk·ōk·ūnāt)*	*gūnitlk·ūnāt*, 'mule' (lit. 'it has big ears').
Eye .	*tlētl* *k·tlētl*	*āqkā'k·tlētl*	*tlittlētl*, 'blind' (lit. 'deprived of eyes'). *ā'qkōmā'k·tlētl*, 'eye-lashes.' *kā'umini'k·tlētl*, 'lower eye-lid.' *mā'tlnāk·tlē'tlnē*, 'he opens his eyes.'

—	Form in Composition	Independent Form	Examples of various Compositions
Finger .	*k·ā'inām*	*ā'qkitsk·ā'inām*	*gō'ts'mā'kansk·ā'inām*, 'first finger.'
Fire .	*k·ō'k·ō*	*ā'qkink·ō'k·ō*	*sā'nink·ōk·ō'nē*, 'the fire is bad.'
			wi'tlink·ōkō'nē, 'there is much fire.'
Hair (of animals)	*k·ōwāt*	*āqk·ō'wāt*	*intcūk'k·ō'wāt*, 'mouse-coloured' (lit. 'mouse hair').
Head .	*tlām*	*ā'qkōtlā'mnām; āqktlā'mnām*	*kānō'hōstlā'm na'na*, 'little red head' (a bird, spec. ?).
			āqkō'tlāmk·ā'kɛnām, 'head of hair.'
Horn .	*k·tlē*	*āqkō'k·tlē*	*gūwi'tlk·tlē*, 'mountain sheep' (lit. 'it has big horns').
House .	*tlā; kītlā*	*āqkitlā'nām*	*kākītlā*, 'my house.'
			tlā'nē, 'the house is.'
Lake .	*k·ɛnūk*	*āqkō'k·ɛnūk*	*skik'k·ɛnū'ksī*, 'there is a lake.'
			qōpā'k·ɛnūk, 'bay in a lake.'
Red .	*nō'hōs; nōs; nūs*	*kānō'hōs*	*ki'tɛnūsitlmē'yit*, 'red sky at sundown.'
			kitɛnū'stik, 'to paint the face.'
River .	*mitūk*	*ā'qkinmi'tūk*	*na'imanmitū'kinē*, 'there are two rivers.'
			k·ō'nänmi'tūk, 'down stream.'
Sand .	*kōkōtl*	*ā'qkinkō'kōtl*	*kämā'nkōkō'tl*, 'Sand Point' (place-name).
Sky .	*itlmi'yit*	*āqkitlmī'yit*	*sānitlmī'yit*, 'bad weather.'
			kānū'sitlmī'yit, 'aurora' ('red sky')
Snow .	*tlū*	*āqktlū*	*nātlū'nē*, 'it is covered with snow.'
			tlōma'iyēt, 'spring.'
			gwāmu'ktlū, 'Chinook wind.'
Star .	*itlnō'hōs; nō'ōs*	*āqkitlnō'hōs*	*gū'witlnō'hōs*, 'evening star' (lit. 'big star').
			kämā'ktcanō'ōs, 'Yellow Star' (personal name).
Tail (of animal)	*k·āt*	*āqk·ā'tɛnām*	*tlitk·ā'tinē*, 'it has no tail.'
Leaf .	*kōtla'kpē'k*	*ā'qkōtla'kpē'kɛnam*	*gī'kōtl·a'kpē'kā'tl*, 'lettuce.'
Leg .	*sāk*	*āqksāk*	*kā'tsk·ākī'tlsāk*, 'Sioux' (lit. 'charcoal legs').
			gōwā'nsāk, 'to crook the leg at the knee.'
White .	*nū'qtlō*	*kämnū'qtlō*	*gī'ānūqtlū'm'nā*, 'rabbit.'
			ā'qkinūqtlū'tlām, 'white-headed eagle.'
Tail (of bird)	*nūkmāɛnā*	*ā'qkinū'kmā'ɛnam*	*gōwi'tlnūkmā'ɛnā*, 'peacock' (lit. 'big tail').

This use of independent and composition forms, differing in the way indicated above, is very extensive in Kootenay, but the manner in which the differentiation of the two is brought about—simply by the addition or the subtraction of particles, each of which no doubt will be discovered in time to have some definite signification—marks the language off from those tongues in which a similar distinction is brought about, according to some writers, by the arbitrary dropping of one or more letters of the independent form. These letters, however, may ultimately be found to have each its particular meaning, and then the arbitrary cutting down of a word, so much spoken of, may be explained as a regular grammatical process.

The independent and the composition forms in Kootenay appear to be from the same radical, which fact distinguishes the language from those tongues in which there is often no connection between the independent form of a word and the form used in composition.

Onomatology and Sematology.

Explanations of some of the names of individuals and places are given below. The following list will serve to indicate the nature of very many of the compound Kootenay names and appellatives:—

apple	*gō'tlwā* (*i.e.*, 'rose-hip').
axe	*āqkō'tātl* (*i.e.*, 'flint').
bald	*gānū'qtlōk* (cp. *kämnū'qtlū*, 'white').
blind	*tli'ttlētl* (*i.e.*, 'without eyes').
candy	*gā'ktlētl k'kō'ktcī* (*i.e.*, 'variegated sugar').
chief	*nāsū'kwēn* (*i.e.*, 'he is good'?).
dumb	*tlittlō'kwā* (*i.e.*, 'unable to speak').
horse	*k'k'ā'tlaqā'ɛtltsin* (*i.e.*, 'elk dog').
light (*levis*)	*tli'ttsɛmā'kā''nē* (*i.e.*, 'not strong').
mallard	*kā'nk·ūskō'ik·āk* (*i.e.*, 'red foot').
mirror	*ki'tɛnū'stēmō'tl* (*i.e.*, 'instrument used when painting the face').
moon	*k'tcitlmī'yit natā'nik* (*i.e.*, 'night sun').
mule	*gū'witlk·ū'wāt* (*i.e.*, 'it has big ears').
needle	*tlō na'na* (*i.e.*, 'little awl').
peas	*āqk na'na* (*i.e.*, 'little cartridges; shot').
plant (spec. ?)	*ā'qkāktlē'tlēs skinkūts* (*i.e.*, 'eyes of coyote').
priest	*kä'mk·ōk·ō'kōtl kā'tuwū'mtlāɛt* (*i.e.*, 'black shirt').
quarter of a dollar	*qā'nkō* (*i.e.*, 'muskrat skin').
rabbit	*gī'ānūqtl'ūm'na* (cp. *kämnū'qtlū*, 'white').
spring (*ver*)	*tlātli'ttlō* (*i.e.*, 'no more snow').
star	*ā'qkitlnō'hōs* (cp. *kānō'hōs*, 'red').
sugar	*k'kō'ktcī* (*i.e.*, 'sweet').
thistle	*nūtlā'kinē* (*i.e.*, 'strange').
train	*ā'qkink·ō'k·ō gākā'ī* (*i.e.*, 'fire waggon').
turkey	*gōwi'tlkā t'ā'nkūts* (*i.e.*, 'big grouse').
watch	*natā'nik na'na* (*i.e.*, 'little sun').
whisky	*wū'ū* (*i.e.*, 'water').
	ni'pik·ā wū'ū (*i.e.*, 'spirit water').
	nūtlā'kinē wū'ū (*i.e.*, 'strange water').
	sūyä'pī wū'ū (*i.e.*, 'white man's water').
wife	*titlnā'mū* (*i.e.*, 'old woman').

REDUPLICATION AND ONOMATOPŒIA.

Formations by reduplication and by onomatopœia seem to be very rare in Kootenay. But a few examples can be given:—

d'nān	magpie.
k·ōk·ū'sk·ī	blue-jay. (This imitative word, in various slightly differing forms, is found in many Salishan dialects.)
sūksōk	a large black bird (spec. ?).
tcōtcō	fish-hawk.
wi'tcwitc	a small river-bird (spec. ?).
qāqā	crow.
nānā'kī	rook.
pu'pū	hammer of stone.
pūs	cat.

It is worthy of note that the word for 'cat' is not reduplicated, as in the Chinook jargon (*pūspūs*).

Personal Names.

No name-feast appears to have existed amongst the Kootenays. The relatives gathered together, and some old man or old woman bestowed a name (*ā'qkītlī'yäm*) upon the child; often, however, the parents named their own child. Frequently the child was given the name of his parent, and thus many names are now in existence, the signification of which has been forgotten, but which have been hereditary in the

family for generations. The custom of dropping a word which resembled, or was the same as, the name of a chief, &c., who had just died appears to have existed amongst these Indians in the past, but the writer was unable to obtain any examples of its application. The Indians are very loth to tell their names, and it is often even difficult to get an Indian to name a particular individual who is pointed out to him. Many of the Kootenays now use their 'mission names,' to the exclusion of their real Indian ones.

The following examples of Kootenay personal names may prove of interest:—

Upper Kootenays: *Gōwi'tlkū Kā''kēn* (Big Wolf); *K'k·ā'tlsāɛn Mā'iyūk* (Three Weasels); *Gōwi'tlktlē* (Big Horn Sheep); *Mūk'* (Bone); *Ktsā'ɛntlā'ɛm* (Curly Head).

Lower Kootenays: *Mā'iyūk Ni'dlkō* (Weasel Iron); *Nū'kē* (Stone); *Ni'dlkō Dli'sin* (Iron Paddle); *Sū'k'nipē'k·ā* (Good Spirit); *Kā'dlsānōkmā'ɛnā* (Three Bird-tails); *Djōqō'min* (Pismire); *Kāmū'ktcānō'ōs* (Yellow Star).

Children are often called after their parents: thus, *Kō'mō Na'na* (Little Kō'mō); *Gīā'tlā Na'na* (Little Swallow), until coming of age, when they assume other names.

An Indian may have several names referring to personal peculiarities, deeds accomplished, and the like. One old fellow, called Patrick, had more than twenty names. The writer was able to obtain only ten of these, as follows:—

1. *Gānkā'tlāmmā'tlāk.* His head is hurt.
2. *Gā'tlānqā'nkō.* He carries trees.
3. *Gōwō'ktlūtla'qa.* He has hair on his chin.
4. *Gānū'qtlōtlutla'qa.* He has a white beard.
5. *Gīyū'nātlā'kō.* He has many pockets.
6. *Kū'pskētlōni'tlētl.* He is feared by all.
7. *G·ā'kātli'sāk.* He has no long braid of hair.
8. *Gā'tlɛmā'kastlā'ɛkāk.* He has big nostrils.
9. *Kɛmā'tlēk.* He turns in his toes when walking.
10. *Gā'tlōgwa'q'nīyāu'wē.* He has little food, and is very angry.

Following are a few names of females: *Gā'k'tsē, Tlikkest, Kɛpa'ka, Tlāitlnā'tlōkwit, K'tsū'kin.*

Some of the names given by the Indians to white men are interesting: *Ski'nkūts* (Coyote), *Kā'kutskā'iyū'kwā* (Bad Hat), *Kākā'qtliqki'nmik* (the man who takes out his eye, *i.e.*, who has a glass eye), *Kākū'mkāk* (blind of one eye), *Kānū'qtlūk* (bald).

The name given to the writer by the Upper Kootenays was *Kīkī'nākī'nkānā'kasnā'mis*, which was said to mean, 'he uses the long stick,' in reference to his anthropological measurements.

Place-names.

The Rocky Mountains, the Columbia River, the Kootenay Lake, are usually called by the Indians: *Aqkā'kōūtlē'et, Aqkinmi'tūk, Aqkō'k·ɛnūk*, which mean simply 'mountains,' 'river,' 'lake' respectively. The two Columbia Lakes (Upper and Lower) are known as *Aqki'skɛnūk* (=two lakes near each other?), the Kootenay River, *Aqkōktlā'qātl.* Other names of interest are: Ainsworth (B.C.) *Aqk'nū'ktlē'ēt na'na* (Little Plain), Barnard (B.C.) *Aqkū'nok*, Bonner's Ferry (Idaho) *Yā'kōkwā'skē* or *Aqkō'kpunmitū'kqō*, Fort Steele (B.C.) *A'qk'ām*, Cranbrook (B.C.) *A'qkisg·ā'ktlēēt*, Kicking Horse River, *A'qkinū'ktlūk*, Sand Point (Idaho) *Kāmānkō'kōtl.*

The Kootenays call their country *Kī'tōnā'qa āmā'kis* (the Kootenays' land). The Lower Kootenays call the United States *Dlā'nē* (the other side) or *Bo'stɛn āmā'kis* (country of the Americans), Canada being denominated *Kindjâte āmā'kis* (the country of the British), the two words *Bo'stɛn* and *Kindjâte* having been adopted from the Chinook jargon.

Seasons, Months, &c.

The names of the seasons are as follows:—

Spring.	*Tlū'māiyēt.*	'When the snow leaves.' Also *tlātli'ttlō* (no more snow).
Summer.	*Gāksū'kit.*	'When things are getting warm.' Also *tlūmā'iyēt nā'mū.*
Autumn.	*K'tcūpnā'kōt.*	'When the leaves, &c., fall.'
Winter.	*Wā'nūīt'nā'mū.*	'When snow and rain come.'

The month-names are :—

January	*Nāktā'isōk* (U. K. and L. K.). 'The beginning (?) month.'
February	*Nipkō'isōk* (U. K. and L. K.). 'The month of the black bear with young.'
March	*Tlikō'k* (U. K.) / *Dlikō'k* (L. K.) 'The month when the water still remains on the ground.'
April	*Gāqku'mēk* (U. K. and L. K.). 'The month when the earth (*ä'māk*) breaks open.'
May	*Otlū'mēn* (U. K.) / *Odlū'mēn* (L. K.) 'The month when the rivers rise.'
June	*Gō'kōkū'pkō* (U. K.). 'Month when the *kū'pkō* ripens.' / *K·āinā'mū* (L. K.). 'The month of the ducks with young.'
July	*Gō'kūsk·ō'mō* (U. K.). 'The month when the service-berries (*sk·ō'mō*) ripen.' / *Ktcidlmū'yitkɛdli'qūwā'iitsk·ū'mō* (L. K.). 'When the service-berries ripen at night.'
August	*Ktcitlmī'itkɛtlē'kɛwā'ɛt* (U. K.). 'When the service-berries ripen at night.' / *Asā'dlɛnik* (L. K.). 'Time of fish-spawn (*anik*).'
September	*Kōpa'kpē'k.* 'Month when leaves begin to fall.'
October	*K'tā'tlōōktcū'pk'ā* (U. K.) / *K'tā'dlōk tcū'pk'ā* (L. K.) 'The month of the rutting of deer' [lit. 'the white-tailed deer (*tcū'pk·ā*) call out'].'
November	*Mist'āmū* ?
December	*Gō'tlmākā'kō* (U. K.) / *Gōdlmā'kākō* (L. K.) 'Time of the ripening of certain berries.'

Both Upper and Lower Kootenays gave but twelve months. Possibly their reckoning has been changed by reason of white influence, or, perhaps, one month (January ?) may count for two. The word now used for month is *natā'nik* (moon); 'year' is rendered by *mā'k·ōt*; also by *mä'ktēt*, translating the jargon expression 'snow.'

The days of the week, introduced by the missionaries, are known as follows in Upper Kootenay :—

Sunday, *gōkwē'tsin mē'yēt.*
Monday, (*tlā*) *ō'kɛn mē'yēt.*
Tuesday, (*tl*) *āi mē'yēt.*
Wednesday, (*tlā*) *g·ā'tlsan mē'yēt.*
Thursday, (*tlā*) *qā'ɛtsan mē'yēt.*
Friday, (*tlā*) *yē'kun mē'yēt.*
Saturday, (*tlā*) *ɛnmi'san mē'yēt.*

Lower Kootenay names the same with substitutions *dl* for *tl*, and *-mō'yēt* for *-mē'yēt.*

The name for a clock is *natā'nik* (sun), and a watch is *natā'nik na'na* (little sun). Time of day is now expressed as follows :—

one o'clock, *gō'kwē natā'nik na'na.*
what o'clock ? *k'ā'k·sā natā'nik na'na ?*
eleven o'clock, *ē'tōwō'm tlā ō'kwē natā'nik na'na.*
half-past eleven, *ē'tōwō'm tlā ō'kwē stlākā'iyakā'wō natā'nik na'na.*

Adjectives.

Adjectives usually precede the noun; the exceptions, such as the words for 'male, female' (not always), 'small' (the adjective *na'na* always), to this rule are few. The adjectives may be classed as follows :—

1. Disjunctive adjectives, which cannot properly be regarded as mere affixes; as, *kɛ'skō* (male), *na'na* (small), *k'ā'pē* (all), &c. Examples :—

qā'ɛtltsin kɛ'skō, dog.
qā'ɛtltsin stō'kwātl, bitch.
k'ā'pē ä'māk, all the earth.
tā'wō na'na, revolver.

2. Those used with the verbals *-nē*, *-inē*, *-kā'nē* :—

sū'kinē ti'tk'āt, the man is good.
wi'tlkā'nē, he is large, tall.
si'qinē, he is fat.
ni'sinē gāā'qktlik, my foot is sore.
yū'nākā'nē tinā'mū, there is plenty of grease.
wa'qinē, it is thick.
wi'tltlānā'mnē, he has many houses.

3. Those used with the prefix *gū-* (*gō-*), and with or without a suffix :—

gōwi'tlkā nāsū'kwēn, a big chief.
gōwi'tlkā wɛ'tāk, a big frog.
gūwi'tlk·ūwāt, mule (lit. 'big-eared').
gūwō'konmi'tūk, a long river.
gūwi'tlk·tlē, mountain sheep (lit. 'big horn').

4. Compound adjectives :—

tcam na'na, few (cp. *tsamā'kētl*, 'very').
k'pä'ktsī na'na, thin.
gō'kō na'na, short.

5. Adjectival periphrases :—

sā'nitlūī'nē, angry (lit. 'bad-hearted he is').
sā'nitlqō''nē, sick (lit. 'bad-bodied he is').

6. Adjectives of colour. These appear to be mostly compounds, and to contain a separable prefix, *kā-*, or *kām-* (*kām-*). Thus :—

kämnū'qtlū, white. *A'qkinūqtlū'tlām*, white-headed eagle. Perhaps the radical is *tlū* (snow).
kā'mk·ōk·ō'kōtl, black.
kämā'qtsē, yellow.
kānō'hōs, red. *Nānō'sg·ōā'tē*, it is red; *ā'qkitlnō'hōs*, star; *kitɛnū'stik*, to paint the face.
kā'ɋtlū'īyit'kā, green.

7. Many adjectives are in constant use as nouns :—

kä'mk·ōk·ō'kōtl, negro.
kānō'hos, species of dragon-fly with reddish body.
kɛ'skō, boy, horse, dog.
stōkwā'tl, girl, mare, bitch.

Diminutives.

As far as ascertained at present, diminutives proper do not appear to exist in Kootenay. Their place is taken—

1. By special words :—

āqktō, a bear one year old.
ā'qkinkū'mātl, calf.
tlkā'mū, little child.

2. By nouns followed by the adjective *na'na*, small, young :—

tlā'utlā, grizzly; *tlā'utlā na'na*, little (young) grizzly.
yāk·tsō'mētl, canoe; *yāk·tsō'mētl na'na*, small model of a canoe.
nāū'tē, woman; *nāū'tē na'na*, girl.
tlō, awl; *tlō na'na*, needle.
gūwi'tltlām na'na, little big-head (bird, spec.?).
Kō'mō (personal name); *Kō'mō na'na*, young Kō'mō.
gäs na'na, the young of the fish called *ipāt*; *pūs na'na*, kitten, &c.

Although *ɋā'ɛtltsin na'na*, and *k'ā'tlaɋā'ɛtltsin na'na* are in use, the ordinary word, both for 'pup' and for 'colt,' appears to be *tci'tɛ na'na*, evidently a compound

with *na'na*. For 'colt' the word *mi'stak·ā'dlā* (in which *k·ā'dlā* = horse) is colloquial amongst the young men of the Lower Kootenays.

Diminutives form their plural and dual as nouns. *E.g.* :—

nāū'tē na'na ki'stik, two girls.
nāū'tē na'na ki'ntik, girls.

NUMERALS.

1, ō'kē; ō'kwē.
2, ās; äs.
3, k·ä'tlsa; k·ā'tlsa.
4, Qā'Etsa.
5, iē"kō.
6, enmi'sa.
7, wistä'tla; wistä'tla.
8, wōQā'Etsa.
9, k·āiki'tūwō'.
10, ē'tūwō'; i'tūwō'.
11, ē'tūwō' tlā ōkwē.
12, „ „ ās.
13, „ „ k·ā'tlsa.
14, „ „ Qā'Etsa.
15, „ „ iē"kō.
16, „ „ nmi'sa.
17, „ „ wistā'tla.
18, „ „ wōQā'Etsa.
19, „ „ k·āiki'tūwō'.
20, ā'iwō; ē'tūwō' tlā ē'tūwō'.
21, ā'iwōm tlā ō'kwē.
22, „ „ ās.
23, „ „ k·ā'tlsa.
24, ā'iwōm tlā Qā'Etsa.
25, „ „ iē"kō.
26, „ „ nmi'sa.
27, „ „ wistā'tla.
28, „ „ wōQā'Etsa.
29, „ „ k·āiki'tūwō'.
30, katlsā'nūwō.
31, „ tlā ō'kwē.
40, Qā'Etsā'nūwō.
41, „ tlā ō'kwē.
50, iēko'nūwō.
51, „ tlā ō'kwē.
60, enmisā'nūwō.
61, „ tlā ō'kwē.
70, wi'stātlā'nūwō.
71, „ tlā ō'kwē.
80, wōQā'Etsa'nūwō.
81, „ tlā ō'kwē.
90, k·āiki'tūwū'nūwū.
91, „ tlā ō'kwē.
100, gi'tūwū'nūwū; ē'tūwū'tli'tūwū'-nūwū'.
101, ē'tūwū'tli'tūwū'nūwūm tlā ō'kwē.
110, „ „ ē'tūwū'.
120, „ „ a'iwō.
195, „ „ k·aiki'tūwū'nūwūm tlā iē"kō.
200, ā'sitl(E)i'tūwū'nūwū.
300, k·ā'tlsa tlEi'tūwū'nūwū.
400, Qā'Etsa tlEi'tūwū'nūwū.
500, iē"kō „
600, enmi'sa „
700, wistā'tla „
800, wōQā'Etsa „
900, k·āiki'tūwō' „
1,000, ki'tūwū'nūwūtlEi'tūwū'nūwū; ē'tūwū'nūwūtlEi'tūwū'nūwū.

In certain cases the letter *n-*, or *g-* (*k-*), is prefixed to the numerals; the reason for this is not known. Thus:—

gō'kwē natā'nik na'na, one o'clock.
Qātlqō'ne āqksā'kēs kō'kwēs, he carries one leg.
nāsnē ni'pinē, two are dead.
nē'tūwū'nē ni'tlkō, ten dollars.

Regarding the numeral system of the Kootenays, the following remarks may be made. The words for *three*, *four*, *six*, contain a suffix *-sa* (*-sā*). *Four* and *eight* are clearly related, the latter being possibly the second four. In the decades a suffix *-wō* (*-wū*) is found, which makes it appear that 'twenty,' *ā'iwō*, is 'two tens.' This is confirmed by the fact that a word *ai* (*āi*) = 'two' does really exist, though only in certain phrases and compositions. *E.g.* :—

kāimā'kwōt, two years; *nā'iman mitū'kinē*, there are two rivers, &c.

In certain locutions: two rivers running into each other, two trees, mountains, side by side; two sticks, and especially when speaking of two plates, cups, pails,

forks, boxes, &c., set one within the other, or of two pairs of breeches, two coats, hats, &c., worn one over the other, *ai* (*āi*) is used. Examples:—

na'iman mitū'kinē. There are two rivers.
„ *kā'ɛnē.* „ „ „ sticks.
„ *itsqlā'ɛnē.* „ „ „ trees.
ka'iman k'ū'nān. Two teeth.
na'imatli'kinē. There are two tracks in the snow.
na'imanqō'mē. Two logs lying side by side.

Ordinals.

The ordinal numerals are:—

ō'smik; ō'smēk, first.
kāsō'sā'tl, second.
itlnā'hak; ka'iyāk'ā'wōsa'qē, third.
a'nitlnā'hak, fourth.

These ordinals take the inflectional *-s* like adverbs.

The words for 'third' and 'fourth' are closely related to *itlkā'hak*, 'far, at a distance.'

Above 'fourth,' and sometimes for all above 'one,' the cardinals are apparently in use.

Numeral Adverbs.

nō'kē'nē nā', *ō'kēnā'* once; *nā'snē nā*, twice; *k'ātlsā'nē nā*, three times, &c.

In these words *nā* probably signifies 'here,' 'now.'

Another series is:—

gōkwē'nātl, once.
gāskā'tlētl, twice.
k'ā'tlsaqā'tlētl, thrice.
qā'ɛtsaqā'tlētl, four times, &c.

Another:—

hō'pāk, the first time; *kānō'pak, kōqū'pak*, that one first (?).
(*tlā*) *kā'senātl*, the second time.

Distributive Numerals.

gōk' kä'ntik, one each.
gās kä'ntik, two each.
k'ā'tlsa kä'ntik, three each.
qā'ɛtsa kä'ntik, four each, &c.

Partitive Numerals.

kā'iyāk'ā'wō; tsɛkūsɛ'k'ā, half.
ō'kē tlɛtsɛkūsɛ'k'ā, one and a half = *ō'kē tlā kā'iyāk'ā'wō.*

PERSONAL PRONOUNS.

The disjunctive pronouns are:—

kā'min, I.
ni'nkō, thou.
ni'nkō'is, he, she.
nē = he.
kā'minā'tlā, we.
ni'nkō'niskē'tl, you.
ninkōi'sis, they.

The word for 'he' looks like a genitive of *ni'nkō*, 'thou.'

These pronouns are used where the verb is not expressed, in answer to questions, &c.; *e.g.*:—

ta'qas ni'nkō! you [have said] enough!
kākē'nē i'ntlāk 'ō'smik kā'min.' Says the chicken-hawk, 'I [will go] first.'
Māts kā'min! Not I!

The pronoun *nē*, in the objective case form *nē'is*, is very frequently used as the

object, or as the complementary object, of verbs, where the incorporated pronoun does not occur; thus:—

ipi'tlnē nē'is tlā'utlās. He kills him the grizzly.
ipi'tlnē nē'is na'ɋanēs. He kills him the caribou.

The subject pronouns used with verbs are:—

hō . . . nē = I.	*hō . . . nātlā'(nē)* = we.
hin . . . nē = thou.	*hin . . . niskē'tlnē* = you.
— . . . *nē* = he.	— . . . *nē* = they.

It is interesting to note that, in the past and future tenses of the verb, the first personal pronoun seems to be *gū-* (*kū*), *e.g.*:—

gūtsɋā'tlip, 'I will kill'; *mā'kūtstlā'kētl*, 'I loved.'

The incorporative forms of the personal pronouns as objects have been given by Dr. Boas ('Report,' 1889), and the examples given below in treating of the verb will suffice to illustrate their use.

ADVERBS.

The position of adverbs in the sentence varies, as the following examples show:—

Pi'kāks i'pinē kä'mā. Long ago my mother died.
O'ɋanē dlī'nis na'ɋanēs. He sees the caribou on the other side.
Ta'ɋas tcina'ɋē wī'tlnām. He went off early in the morning.
Kākē'nē ski'nkūts: 'ō'smik kā'min.' Said the coyote: 'I [will go] first.'
K'känmī'yit wī'tlnām kāki'tlnē ti'tlnāmū'is ski'nkūts. The next day early the coyote spoke to his wife.
Kāna'ɋē ski'nkūts ō'smēks. The coyote goes first.

Adverbs may or may not take the inflectional suffix *-s*. One can say, for example, *pi'kāk i'pinē kä'mā* or *pi'kaks i'pinē kä'mā*. The exact rule for the use of this suffix is not apparent.

I. Time:

Pē'kāk or *pi'kāk*, long ago.
wi'niki'tinē, it is long since.
tāqtā', by-and-by.
nāta'ɋā, now.
ā'qkänmī'yit, always, every day.
känmī'yit, to-morrow.
nā'hōsā'nmēyi'tkē, to-day.
wā'tlkwā, yesterday.
wī'tlnām, early.

II. Repetition:

tlā, again.
ā'qkī, again, more.

III. Place, direction:

nā, here.
nē, there.
tlā'a, outside.
nā'ɛtā, high, up.
ū'mmī, down.
tlē'nē, across, on the other side.
k·ō'nän mi'tūk, down stream.

IV. Interrogation:

k·ā'a, where?
k'ā'kēn, whither?
k'ās, where is?
k'ä'psi(n), what? why?
k'ā'k'sā(n), how much? how many

V. Affirmation, negation:

wa'ɋā, no.
mā'ɛts, no.
ɋē, yes, certainly.
nā'qk·an, perhaps.

Adverbial offices are also performed by certain prefixes and suffixes, and by letters attached to the verb. These are discussed elsewhere.

Iterative Adverb.

The adverb *tlā* is used with compound numerals and with verbs denoting repeated action, *e.g.*:—

ē'tūwō' tlā ō'k·wē, 'eleven' (lit. 'ten again one').
ō'kētlɛtsɛkū'su'k·ā, 'one and a half' (lit. 'one again piece').
tlā'wānē'nē, 'it bobs up and down.'
tlāwa'ɋē, 'he returns.'
tlā'tcina'ɋē, 'he goes away again.'

Negation.

There are two disjunctive adverbs of negation, *mā'ɛts* (or *māts*) and *wa'ɋā*. The distinction between them seems to be this: *wa'ɋā* is equivalent to the English 'no, not that; that is not right; don't do that'; while *mā'ɛts* is used with pronouns and verbs in the imperative, and also in cases where a contradiction and a correction is intended. Following are examples:—

Mā'ts kā'min! Not I! (*i.e.*, someone else may do it).
Mā'ɛts itki'nin! Do not do it!
Mā'ɛts klō'nē, tlō'nē. Not *klō'nē* but *tlō'nē*.
Tcin ni'tlkō mā'ɛts āqkōkpō'ō. The iron [barrel of the gun] not the stock.
Kinū'was? wa'ɋā. Are you hungry? No.
Kākē'nē tlā'utlā: 'wa'ɋā!' Said the grizzly bear: 'Don't do that!'
Kākē'nē i'ntlāk: 'ō'smik kā'min.' Kākē'nē ski'nkūts: 'wa'ɋā.' Said the chicken-hawk: 'I [will go] first.' Said the coyote: 'No.'

In conjugation and word formation the negative particles *k·ā*, 'not,' and *tlit*, 'without,' 'deprived of,' are employed. They are sometimes prefixes and at other times infixes. Examples:—

K·āi'nē si'nā. It is not beaver.
kō'k·āō'pɋanē. I do not see.
hō'k·āi'kinē. I do not eat.
hō'k·āi'sinētlā'nē. It is not my house.

hōtli'ttāwū'tē. I have no gun.
hōtli'stē āqktcā'mātl. I have no knife.
tli'ttlētl, blind (*-tlētl* = eyes).
tli'ttlātli'tit, unmarried man (*tlātli'tit* = married man).
tlittsɛ'mā'kā''nē, it is light (*tsɛ'mākā'nē* = it is strong).

The radical *tlit* is seen in *tli'tkɛm* 'worthless.'
There is still another particle, *tlō* (probably = 'none left') used as follows:—

tlō'nē ni'tlkō. There is no money.
tlō'nē. There is no . . . .
tlō'sī, „ „ . . . .
tlō'nē k'ä'psin. Nothing.
tlō k'ä'psin. Nothing.

Conjunctions.

Few conjunctions have as yet been determined. The equivalents of some English conjunctions are:—

A'qkī, and, more. *Kā'min ā'qkī ni'nkō.* I and you. *A'qkī ni'nkō.* You too. 'And' in the numerals is expressed by *tlā; ētū'wōtlāō'kwē* (ten and one), eleven.
K'ä'psin, why. *K·āō'pɋanē k'ä'psin tsi'tlēp.* He does not know why she is dead.
Pā'tlk, because. *Pā'tlk'si'tlēp.* Because he was dead.
Nā'pēt, if. *Nā'pēt hintsi'nām.* If you go.

Interjections.

But little was learnt regarding these words. A few are real interjections; the rest are parts of speech used interjectionally.

hā'ɛ! hā'ɛ = aha! (expression of surprise.)
ā! = Get out of the way (used to dogs). For human beings *tlū'nū!* (go away!) is employed.
ā'hā hē'ī! Ah, that is good! I like that.
hā'i ī! That is not good! I don't like that.
hā'ī yū! Hallo! That's strange!
yōhō! Hurry up! (from English?)
mɛ'kāk! Hold on! Not so fast!
Ta'ɋas! Stop! Enough!

VERBS.

The Verb 'To Be.'

The duties of the substantive verb appear to be performed to some extent by *ɪnē*, *-inē* (*-ne*). Thus:—

Hōni'nē Ki'tōnā'ɋa = I am a Kootenay.
Kākē'nē 'hōni'nē ski'nkūts' = he says 'I am the coyote.'
I'nē si'nā āqkō'tātls = it is beaver-grease.
Ni'nē sūyā'pī = he is a white man.
Tlāk·ā i'nsī ski'nkūts ti'tlnamō'is g'ū'stēt = the coyote is not the wife of the trout.
Ni'nsī ti'tlnamō'is g'ū'stēt = it is the wife of the trout.

Often no verb or suffix is employed, as *kā'min ski'nkūts* = I am the coyote.
This *ēnē*, *-inē* (*-nē*) seems to be the same as the suffix *-ēnē*, *-nē*, *-nī*, found in adjectives and some intransitive verbs, *e.g.* :—

sūki'ni = it is good.
si'qinī = it is fat.
i'pinē = he is dead.
wa'qinē = it is thick.

The Verb 'To Have.'

The verb 'have' appears in some cases to be expressed by the suffix *-tē* :—

hō'iē'kō'tē k'ā'tlaɋā'ɛtltsin = I have five horses.
hō'nāsk·ā'tltē = I have two children.
hōnā'tē āqkō'tātls = I have an axe.
hō'yūnā'tē nū'mōs = I have many beads.
hōtli'tānū'tē = I have no gun.

Past Tense.

The tense-sign for past time is *mā-*. The following examples will serve to indicate its use :—

mā'kūtstlā'kētl = I loved him.
mā'kōō'pɋanis = I saw you.
mākī'ēp = he died.
māktsēkūtl = he drank.

Future Tense.

The future tense-sign is *ɋātl* :—

hā'tsɋātli'kinē = I shall eat.
kū'tsɋātli'pitl = I shall kill.
tsɋātli'pitl = he will kill.
hōtsɋā'tlēkū'tlnē = I shall drink.
tsɋā'tlɋōna'ɋē = it will go.
hōtsɋā'tli'nē = I shall be . . .
gū'tsɋātlkā'kētl = I shall tell.

The desiderative coincides with the future :—

tsɋā'tlāna'ɋē = he wants to hunt.
kiutsɋā'tlēk = do you want to eat?
hō'tsɋātli'kinē = I want to eat.
k'tsā'tli'tɋa = he wants to bite.

Imperative.

In this mood, as is the case in many languages, the radical of the verb is easily seen. The following examples will suffice :—

i'kē(n) = eat thou!
ōwō'kēn = get up!
tcēkā'tēn = take care!
shā'kin = give me!
itki'nin = do it!
māts ōni'tlin = don't be afraid!
k'k·ō'mnē(n) = sleep thou!
tlā'ne = come!
tlū'nō = go away!
piski'nō = let go!
tcēkā'tō = look!
hä'māti'ktcū = give!
tlā i'tɋanō = bite me again!
isä'kinōn = sit down!
i'kētl = eat ye!
nū'pkētl = sleep ye!
k·ōmnē'kētl = sleep ye!
tsinā'kētl = hurry up!

There appear to be several endings for the imperative, but the chief are *-ē*, *-ēn*, *-ō* for the singular, and *-ētl* for the plural.

Interrogative.

The interrogative form of the verb is made up of the particle *kin* (you) and the radical of the verb, with tense-signs :—

kinēk? = do you eat?
kintsqā'tlēk? = do you want to eat? Will you eat?
kinkā'tlūī? = do you think?
kin ā'kōwitl? = do you dance?
kin ē'tlā? = do you cry?
kintsi'tqa'nāp? = would you bite me?
kin ī'nē Ki'tōnā'qa? = are you a Kootenay?

The inflection of the voice, as in English, indicates that a question is being asked, thus :—

ī'nē si'nā aqk·ō'tātls? = is it beaver-grease?
ī'nē Pōl ā'qkītlā'is? = is it Paul's house?

Negative.

With verbs in the imperative the negative *māts* is used :—

māts itki'nin! = don't do that!
māts i'kētl = don't eat!

The particle *k·ā* is prefixed to the third person of the verb in the indicative mood, and inserted between the personal pronoun and verb in the other persons. Thus :—

k·ā i'nē si'nā = it is not beaver.
k·ā ō'pqanē ski'nkūts = he does not see the coyote.
k·ā tāqā''nē = it is not raining much.
hō'k·āō'pqanē = I do not see.
hōk·ā'wasqō'mēk = I do not sing.

INCORPORATION OF OBJECT.

A peculiarity of Kootenay is the incorporation of noun-objects in the verb, thus :—

hōtstlū'tsk·ātlqō'nē = I take the bark off a tree (bark = *āqkitsk·ā'tl*).
gō'tsūkwā'tlāmki'nmēk = I smooth down my hair with my hands (*āqk·ō'tlām* = hair).
kā'k·ānwū'mātl = to cut open the belly (*āqkō'wōm* = belly).
tlū'k·tsātlā'inē = he cuts off end of nose (*ā'qkinūk·tsā'tlā* = end of nose).
gōwā'ntlik = I move my foot about (*ā'qktlik* = foot).
nā'tltlāmki'nē = he takes [carries] the head in his hand.
wānk·ō'tlāmki'nē = he shakes the head in his hand.

Following are examples of the incorporation of the object pronoun in the verb :—

hōtsi'tqani'sinē = I bite you (*hō-ts-itqa-n-is-i-nē*). Radical is *i'tqa*, 'bite.'
I bite you

hi'ntsqātlhō'tlpātlnā'pinē = you will honour me (*hin-ts-qātl-tlpātl-n-āp-i-nē*)
you hear me
Radical is *hōtlpātl*, 'hear.'

tsqā'tlipitli'sinē = he will kill you (*ts-qātl-ipitl-is-i-nē*). Radical is *ipi'tl*, 'kill.'
kill you

hōtsqātlk·ā'ntlātli'sinē = I will strike you (*hō-ts-qātl-k·āntlātl-is-i-nē*). Radical is
I strike you
k·āntlātl, 'strike.'

nū'pqanā'pinē = he sees me (*n-ūpqa-n-āp-i-nē*). Radical is *ū'pqa*, 'see.'
see me

hinū'pqanā'pinē = thou seest me (*hin-ūpqa-n-āp-i-nē*). Radical is *ū'pqa*, 'see.'
you see me

hōnū'pqani'sinē = I see thee (*hō-n-ūpqa-n-is-i-nē*). Radical is *ū'pqa*, 'see.'
I see you

tsqā'tlitqa'nāwa'sinē = he is going to bite us (*ts-qātl-itqa-n-āwas-i-nē*). Radical *bite us*

i'tqa, 'bite.'

tsqa'tltcū'kwāti'sinē = he is going to get you (*ts-qātl-tcūkwāt-is-i-nē*). Radical *get you*

tcū'kwāt, 'get.'

PREFIXES.

The prefixes *n-* and *g-* (*k-*), perhaps the same as those appearing in the numerals, are found with certain forms of the verb. In others they do not appear. Their signification is not known. The following examples will illustrate their use:—

Pi'kāks i'pinē kä'ma. Long ago my mother died.
Ta'qas n-ā'snē n-i'pinē tlā'utlās. Two grizzly bears died.
Ski'nkūts ipi'tlnē nē'is k'ū'pis. The coyote kills him the owl.
Kākē'nē hōnipi'tlnē kū'pī. He says [said] 'I kill [killed] the owl.'

This *n-* appears in the third person singular of very many verbs, and also in the first person singular. Examples of the prefix *k-* (*g-*) as compared with *n-*, and the verb without prefix are—

g-ō'kū sk·ōmō, month of July (lit. 'when the service-berries ripen').
n-ōkū'inē āqkō'ōktlē'ēt, the berries are ripe.
gūtlā'ktlē, old (*senex*).
nūtlā'kinē, he is old, an old man.
ki'tɛnū'stik, to paint the face.
hōni'tɛnū'stik, I paint my face.
nā'uwa'nē, he barks.
kō'wē ski'nkūts, the coyote barks.

Other prefixes are *s-*, *k-*, *y-*, as exemplified in the following:—

kānk·ā'mēk skinkūts, the coyote sits on his haunches.
yānk·ā'mēn, sit down!
hō'tsānk·ā'mēk, I sit down.
kā'usakā'nē i'ntlāk āqkī ti'tlnāmō'is, the chicken-hawk and his wife are there.
sā'usākā'nē tlā'ūtlā, the grizzly is there.

OTHER MOODS.

Regarding other moods little can be said at present until the analysis of the language has progressed further. The following examples, however, may be given:—

Kā'tlūī'nē k'tsqātli'pitl ski'nkūts. He thinks to kill the coyote.
Kā'tlūī'nē tsqātli'pitlā'ps. He thinks to kill me.
Hōsā'kitlkā'kinē nī' kōk·ā'ēp. I am very glad that I am not dead.
K·a'ōpqanē k·ä'psins tsi'tlēp. He does not see why he is dead.
Kātlūī'ne hōtli'kimātl āqk·āktlē'tlēs ski'nkūts pātlk'si'tlēp. He thinks: I will eat the eyes of the coyote because he is dead.
Kā'tlūī'nē kē'ēps. He thinks she is dead.

An infinitive or perhaps a participial form in *-sī* [*-sē*] seems to be indicated in the following:—

Hōtlpā'tlne k'ū'pis tātlō'ksī tlā'ne. I hear the owl saying 'come.'
Kāna'qē ā'qkitlnō'hōs, nū'pqanē tlkā'mūs ni'ksī ä'māks. A star comes along [and] sees a child eating dirt.
O'pqanē skā'si tlā'utlās. He sees the grizzly bear coming.
O'pqanē ni'tltsiks skā'sē. He sees the buffalo bull coming.
O'pqanē tlāpskā'sē pāpā'is. He sees his grandmother coming.

Occasionally a form in *-sin* occurs:—

O'pqanē skā'sin k·ā'qkēns. He sees the wolf coming.

These forms in *-sī* [*-sē*] may, however, be dependent forms of the indicative. The following show another verbal form :—

Kākē'nē k·ä'psin gōtlē'tkin. He says : what shall I do ?
K·āō'pqanē k·ä'psins tli'tkin. He does not see (know) what to do.

Following are examples of the verb in the most indefinite form, corresponding perhaps to a verbal noun or an infinitive :—

kō'nētl, to fear, fearing.
kikētl, to eat, eating.
gā'k'tsqātl, to chew, chewing.
qātla'sqōtl, to chop, chopping.
kitk·a'skātl, to cut with shears, cutting.
kitkin, to do, doing.
kātū'k'tsātl, to tie, tying.
qitkā'qātl, to twist, twisting.
kā'kōnī'tlnām, to dance, dancing.
gā'tlūwā'tsinām, to gamble, gambling.
gā'tlk·ātē'inām, to gather berries, gathering.
k'k·ōmnē'nām, to sleep, sleeping.
k·ā'inām, to steal, stealing.
gīyi'ktāmā'tlnām, to upset a canoe, upsetting
tsqā'nām, to say, saying.
kātlē'tcātē'yäm, to dream, dreaming.
gāna'k'nē'yäm, to sit, sitting.
gā'k'ktcē'yäm, to bathe, bathing.
gū'tskī'yäm, to lie, lying.
gā'qkōtlē'yäm, to sell, selling.
mi'tik'ki'mēk, to holloa, holloaing.

EXAMPLES OF VERB-COMPOSITION.

Radical	*ā*, 'to rub, to paint,'	Derivatives:	*yū'ā ki'nē*, he rubs on (*yū-*, on, *-kin*, with hand).
,,	*a*, 'to come, to go.'		*wa'qē*, he comes. *tlāwa'qē*, he returns. *ska'qē*, he comes. *skā'sī*, coming. *kāna'qē*, he goes along. *tcina'qē*, he goes away. *tlā'tcina'qē*, he goes off again. *kā'uqua'qē*, he starts after.
,,	*ātl*, 'to carry.'	,,	*nātlqō'nē*, 'he carries on his back' (*n-*, prefix, *-qō'*, 'on back'). *nātlki'nē*, 'he carries in his hand' (*-kin*, 'with the hand').
,,	*ātlas*, 'to separate.'	,,	*hōnā'tlasē'īqō'mēk*, 'I cut stone.' *gā'tlaski'nitl*, 'to tear apart.'
,,	*ip*, 'dead, to die.'	,,	*ni'pinē*, 'he is dead.' *ipi'tlnē*, 'he kills' (*-tl* transitive suffix). *ipū'kinē*, 'he is drowned' (='to die in the water,' *-ūk*=in water).
,,	*it*, 'to do, to make.'	,,	*kitkin*, 'to make' (*-kin*, 'with the hand'). *nitki'nē*, 'he makes, does.' *i'tqanē*, 'he bites' (='he does with the teeth,' *-qa*, 'with teeth').

nitqō'mēk, 'he lies down' (*n-*, prefix, *-qō*, 'with the back,' *-mēk*, verbal suffix).
gi'tɛnū'stik, 'to paint the face' [red] (*g-*, prefix, *-nūs*, red, *-tik*, suffix).
kitk·ā'skātl, 'to cut with shears' *k-*, prefix, *-k·ā*, 'with shears').
hōnī'tkinmā'tlnē, 'I help' ('I do with the hand along with,' *-mātl*, 'along with, together').

Radical *k'ē*, 'to speak.' Derivatives: *kāk'ē'nē*, 'he says' (*kā-*, prefix).
kākē'tlnē, he says to 'address' (*-tl* = transitive suffix).
gūtski'yäm, 'to lie' (*g-*, prefix, *-ūts* (meaning?), *-yäm*, verbal suffix).

„ *ō'pqa*, 'to see.' „ *ō'pqamā'tlnē*, 'he finds' (= 'he sees together,' *-mātl*, together).

„ *tlēts*, 'to lie on bed, to sleep.' „ *skiktlē'tsinē*, 'he is sleepy.'
kātlē'tsātē'yäm, 'to dream.'

It will be observed that many of the radicals, *e.g.*, *ī* (to be), *ā* (to rub), *a* (to go), *ip* (to die), *it* (to do), *k'ē* (to speak), are monosyllabic, and it is possible that many of the other and dissyllabic radicals, such as *ō'pqa* (to see), *ōtlpātl* (to hear), *ōmāts* (to laugh), *ōwōk* (to rise), *ōnitl* (to be afraid), *ōmits* (to break), *ōwas* (to be hungry), *ōkū* (to be ripe), *ōtē* (to be warm), *ōtlūq* (to be tired), *ōmas* (to be dry), &c., may be compounds. The occurrence of the *ō-* in so many of these radicals is worth notice.

As will be seen from the following list, the suffixes which express the idea of performing an action with a certain portion of the body have nothing etymologically to do with the name of that member:—

Back = *āqktlā'kɛnām*.	To do with the back = *-qō*.
Hand = *āqkē'īnām*.	To do with the hand = *-kin*.
Teeth = *ā'qk'ānā'nām*.	To do with the teeth = *-qa*.

Prefixes.

ai-	two	*a'iwō*, twenty; *n-a'i-man mitū'kinē*, there are two rivers.
ātl-	in terms of relationship	*āqkā'tlē*, son; *ā'tlāqkā'tlē*, grandson.
g-, *k-*, *k'-*	in verbs, numerals, &c.	*ki'tkin*, to do; *k'kō'mnē*, sleep! *k'tcitlmī'yēt*, night; *kō'kwē*; *gāsmā'tlnē*, two together.
kā-	pronominal	*kāna'qē*, he goes; *kākē'nē*, he says; *kā'tlūī'nē*, he thinks; *kānōhos*, red.
käm-	in colour-names	*kämnū'qtlō*, white; *kä'mk·ōk·ō'kōtl*, black.
k·ā-	negative	*k·āwi'nīki'tsī*, not very far.
kī-	in certain verbs and nouns	*kīyū'kwīēt*, day; *kī'tōktli'tlqā'tl*, paper.
-, *-*, *gīā-*, *kāā-*	in animal names	*kīā'wāts*, fool-hen; *gīa'kqō*, fish; *gīanū'kqō*, mountain-goat; *gīā'tlā*, swallow; *gī'ānūqtlū'm'nā*, rabbit; *gī'ānū'k·tlē*, rhinoceros (word applied to rhinoceros seen in an engraving).
kin-	interrogative particle	*kinēk*, are you eating? *kintsqā'tlēk*, do you want to eat?

PREFIXES—*continued.*

kī-	with certain parts of verbs	*kīēp*, dead; *kīēk*, eaten.
kū-, *gū-*	with adjectives and verbs	*gūwi'tlkā*, large; *gūwi'tlk·tlē*, big horn sheep; *gūātla'skin*, to break in two with the hand.
gyā-, *kyā-*	two together, junction (?)	*gyā'khāmā'ɛnam*, junction of two trails; *kyā'ninmi'tūk*, two branches of a river, round an island.
itl-	?	*itlkā'hak*, very far; *ā'qkitlnō'hōs*, star.
nā-	demonstrative	*nā-ū'tē*, woman; *nāsū'kwēn*, chief; *nāhō'sān mēyi'tkē*, to-day; *nāta'ɋa*, now.
n-	with certain numerals and verbs	*nō'kwē*, one; *ni'pinē*, he is dead; *ni'kinē*, he eats; *nipi'tlnē*, he kills; *nā'snē*, there are two.
skik-	demonstrative	*ski'k'k·ɛnū'ksē*, there is a lake; *skik'-nū'k'sī*, there is a stone; *skiktlē'tsinē*, he is sleeping.
tcɛm-, *tsam-*	?	*tcɛmna'na*, few; *tsamā'kētl*, very.
tlā-	again	*tlāwa'ɋē*, it returns; *āi'wōtlāɛnmi'sa*, twenty-six.
tlit-	privative, negative	*tli'tkɛm*, vain, worthless; *tlittlētl*, blind; *tlittlō'kwā*, dumb, speechless.
tlō-	negative	*tlō'nē k'ä'psin*, there is nothing; *tlōk'ä'psin*, nothing.
witl-	large	*witlkā'nē*, it is large; *gūwi'tlkāgīā'kqō*, whale; *hō'witlki'nē*, I shout; *wi'tlīi'tinē*, far; *wi'tltliti'tinē*, rich.
yū-, *yō-*	on, on top of, up	*yū'ākī'nē*, he rubs on; *yōɋua'ɋē*, he climbs to the top; *hō'tsyūɋūa'k'-nū'nē*, I climb the mountain; *yū'tsiki'n*, to press the hand upon anything.
yūnā-	many	*yū'nākā'nē*, there are many; *yū'nān-mitū'kinē*, there are many rivers; *hōyū'nāhē'k'namō'ɛnē*, I have many friends; *yū'nāk'ä'psin*, many things.

THE PREFIX *āq-*.

The most characteristic prefix of the Kootenay language is the noun-prefix *āq-*, the signification of which I have as yet been unable to decide. In some cases it is omitted, and even in giving the most indefinite form some of the Indians did not use it in certain words, *e.g.*:—

wā'tlōna'kɛnam, tongue.

The following list of composition with *āq-* will indicate the manner of its use generally, and may suggest possible explanations of its proper functions:—

āqk, arrow.
ā'qkē, again, and.
āqk·ā'tl, cloud.
āqkä'mē, gopher's hole.
āqkā'wō, cord.
āqktcā'mātl, knife
āqk·āt, tail.
āqk·ā'tlē, son.
āqkā'sāk, shore.
āqkām, white pine.
āqkō, spider's web.
āqk·ōā'tlōwōk, birch tree.
āqka'n, handle.
āqk·a'nāk, ankle.
āqkɛ', thwarts of canoe.
āqkā'tskō, gun-flint.
āqkō'wātl, wild onion.
āqktlōm, bat.
āqkū'tla, pipe-stem.
āqkū'tlak, meat, flesh.
āqktlū, snow.
āqk·ū'tlūm, eel.
āqktlō'māk, cotton-wood tree.
āqk·ē'i, hand.
āqk·ūn, nose.
āqkā'nkō, smoke-hole of lodge.
āqktsāk, leggings.

āqkō'kō, raspberry.
āqkä'minā, creek.
āqkō, pointed ends of canoe.
āqktō, one-year-old bear.
āqktlāk, back.
ā'qkinmi'tūk, river.
ā'qink·ō'k·ō, fire.
ā'qkinū'tlām, snake.
ā'qinkä'māk, dragon-fly.
ā'qink'ā'tl, forehead.
ā'qkinqō'mōtl, button.
āqki'nnōqō'nūk, creek.
ā'qkinū'kmāk', fish-spear.
ā'qkinū'ktlē'ēt, prairie.
ā'qkinū'ktlūk, Kicking Horse River.
ā'qkinkō'tl, sand.
āqki'nkō, forked stick.
ā'qkinkānū'qtlām, crown of head.
ā'qkinū'qmā'ɛnā, tail of bird.
ā'qkītlī'yäm, name.
ā'qkītlā'nām, house.
ā'qkīyē'nik, thigh.
āqki'tlwī, heart.
ā'qkitlmē'yit, sky.
ā'qkitlnō'hos, star.
ā'qkitlmāk', peach.
āqkō'wōm, belly.
āqkō'ktlākō'wōm, cricket.
āqkōkō'wōm, house-fly.
ā'qkōtlā'kō, bag.
āqkō'wōktlē'ēt, mountain.
āqkō'ktla'qa, beard.
āqk·ō'k'ɛnūk, lake.
āqki'ts, lodge-pole.
āqkitsk·ā'inām, fingers.
āqkitsk'ā'tlāk, branch of tree.
ā'qkitsk·ā'tl, bark.
ā'qkitstlā'in, tree.

āqkō'pātl, maize.
ā'qkinni'tlqātl, powder.
ā'qkinnū'mātl, quills.
ā'qkinkō'mātl, calf (*vitulus*).
ā'qkinkō'wā, wings.
ā'qkinū'k·tlē, tomahawk.
ā'qkinū'kayūk, flower.
ā'qkinnākqā'akō, pitch.
ā'qink'ō'mātl, cradle.

āqkātla'ktcū, cord.
āqkīmū'qō, garden.
āqkīyū'kwā, head-dress, hat.

ā'qkōwi'tskō, buckle.
ā'qkōtā'tl, grease, fat.
ā'qkō'k·tlē, horns.
ā'qkōktlā'wō, fishing-line.
ā'qkō'tātl, axe.
ā'qkō'k·omō'k·ō, ashes.
ā'qkitsk·ā'kitl, soot.

The above list of words is not arranged according to any known principle, but merely to illustrate the variety of compositions with *āq-* in Kootenay.

It is evident that *-k*, *-kē-*, *-kin-*, *-kō-*, *-kits-*, *-(k)itl-*, &c., are qualifying affixes, but at present it is impossible to state with certainty their several meanings. In the last group of words in the first column there is the idea of 'tree, branch,' at the bottom of most of them, and in the case of 'star' and 'sky' a correlation is certain. But of the rest of the list nothing can be stated with certainty.

However, *ā'qkinū'tlām*, 'snake,' and *āqkū'tlām*, 'eel,' seem related, as perhaps are also the words for 'belly,' 'cricket,' 'fly.'

It might be mentioned that several words have more than one form, thus:—

tree = *ā'qkitstlā'in*; *ā'qkinätstlā'in*.
head = *āqktlām*; *āqkō'tlam*.
cloud = *āqk·ātl*; *ā'qkink·ā'tlāk*.
sand = *ā'qkinkō'tl*; *ā'qkinkōkō'tl*.
name = *ā'qkītlī'yäm*; *ā'qkōtlī'yäm*.

On another occasion the writer may be able to further discuss this interesting feature of the Kootenay language.

Suffixes.

-ātl	suffix in plant names	*āqkō'-ātl*, onion; *tän-ā'tl*, rush.
-āts	suffix in animal names	*g·ō'tsāts*, chipmunk; *t'a'kāts*, squirrel; *gīā'-wāts*, 'fool-hen.'

SUFFIXES—*continued.*

-ēt *-it*	suffix in names of objects of nature, and atmospheric phenomena	*wātlkwā'ēt*, evening; *kānmē'yēt*, to-morrow; *āqkō'wōqtlē'ēt*, mountain; *ā'qkinūqtlē'ēt*, prairie.
-g·āk *-k·āk*	suffix in names of parts of body	*āqkē'ĭg·āk*, foot of bird; *āqkō'yīk'ā'k*, wrist; *āqkō'ūk·ā'k*, neck.
-k	suffix in animal names	*ntcūk*, mouse; *mā'iyūk*, weasel; *wa'tāk*, frog; *k'u'pōk*, woodpecker; *kō'kwōk*, swan.
-kā	with adjectives and verbs	*witlkā'nē*, he is tall, big; *kā'usākā'nē*, he abides; *yū'nōkā'nē*, many.
-kāhak	with certain adverbs	*itlkā'hak*, very far; *kōitlkā'hak*, far from here.
-kä'ntik	suffix of distributive in numerals and substantives	*nō'kwēkä'ntik*, one stone each; *kāskä'ntik*, two each.
-kin	with hand or foot	*yū'ā'ki'n*, to paint; *ātlkin*, to carry in the hand; *yū'tsīki'n* to press the hand or foot on anything.
-ki'ntik	suffix of collective	*pā'tlkēki'ntik*, several women.
-ki'stik	suffix of dual	*pā'tlkēki'stik*, two women.
-kī	in certain nouns	*yā'kasinki'nawā'skī*, God; *nā'hōsā'nmēyē'tkī*, to-day.
-qō	on, with, the back	*nātlqō'nē*, he carries on his back; *nitqō'mēk* lie down.
-qa(n)	with the teeth	*i'tqanē*, he bites.
-mātl	together	*āsmā'tlnē*, two together; *k'tsāmā'tlnē*, along with, together.
-mēk *-mik*	verbal suffix	*itqō'mēk*, to lie down.
-mē'yēt *-mē'yit* *-mī'yit*	suffix with names of atmospheric phenomena, names of days, &c.	*ā'qkitlmē'yēt*, sky; *k'tcitlmē'yēt*, night; *kānmē'yēt*, to-morrow; *ki'tɛnū'sitlmē'yēt*, red sky at sundown; *kōki'tcinmē'yēt*, Sunday.
-mōtl	suffix with names of implements, instruments, &c.	*ki'tɛnū'stē'mōtl*, mirror; *āqktē'mōtl*, fire-flint; *gānä'nkōmō'tl*, broom.
-nā'hak	in certain adverbs and numeral adjectives	*itlnā'hak*, fourth; *itlnā'haks*, next.
-nē	suffix with predicate adjectives and verbs	*nōni'tlnē*, he is afraid; *i'tqanē*, he bites; *nātlqō'nē*, he carries on his back; *ni'pinē*, he is dead; *witlkā'nē*, it is big.
-nām	suffix of generality with nouns	*āqkitlā'nām*, a house, somebody's house.
-nām	suffix of infinitive (?) with certain verbs	*tsqā'nām*, to speak.
-nik	dwelling at	*āqk'ā'mnik*, Indians of Fort Steele.
-ni'ntik	suffix of plural	*pā'tlkē*, woman; *pā'tlkēni'ntik*, women.
-sa, -sā	suffix of certain numerals	*k·ā'tlsa*, three; *qā'ɛtsa*, four; *nmi'sa*, six.
-sī	suffix of infinitive or participle (?)	*skā'sī*, coming.
-tl	suffix of certain transitive verbs	*i'pinē*, he dies; *ipi'tlnē*, he kills him.
-tlē'ēt	extent of country (?)	*nāmtlē'et*, echo; *āqkinū'qtlē'ēt*, prairie; *āqkō'wōktlē'ēt*, mountain; *gō'witltlē'ēt*, far.
-tlō'k	in certain bird names	*kāqū'tlō'k*, goose; *gāspi'tlō'k*, crane.
-ūk *-ōk*	in the water; water	*tlikōk*, March (water left); *ipū'kinē*, he drowns (dies in the water); *tābū'ksē*, get under water; *ā'qkinmi'tūk*, river; *āqk·ō'k·ɛnūk*, lake; *gīyā'kōk*, water falling over stones.
-wōk	woody substance, shrub, tree	*āqk·ōā'tl'wōk*, birch tree.
-yäm	suffix of infinitive (?) in certain verbs	*gūtskī'yäm* to lie.

SUFFIX *-mōtl.*

The suffix *-mōtl* is a very important one, and is combined with other particles, which have the function of further specialising the instrument. The following list

must be given at present without an exact knowledge of the import of these other affixes:—

with *-tē-*: *āqktē'mōtl*, fire-flint.
ki'tɛnū'stē'mōtl, mirror.
gi'tɛmō'tltlūpkū'ptcētē'mōtl, yeast.
with *-k·ā-*: *gi'tūktlitlk·ā'mōtl*, pen, pencil.
gā'kōqōmāk·ā'mōtl, weighing-scales.
k'pitsk·ā'mōtl, scythe.
kikā'wōk·ā'mōtl, tobacco-cutter.
with *-k·ō-*: *gāt'k·ō'mōtl*, key of metal.
qānā'nk·ōmō'tl, broom.
k'tcōktlā'ink·ō'mōtl, auger.
kitkē'tlwitck·ō'mōtl, nail.
with *-qō-*: *kitā'kōpqō'mōtl*, stick for beating on log.
kitā'mōqō'mōtl, drumstick.
qitō'ktlitqō'mōtl, branding-iron.
with *-nē-*: *ki'tcūkō'nē'mōtl*, fork.
ki'tisū'kwākinē'mōtl, handkerchief.
kik'tū'kōnē'mōtl, soap.
kikā'konēqōnē'mōtl, towel.
with *-ti'te-*: *gōpkō'wātlikō'nate'timōtl*, broom.
kānkā'tlmōkwāti'temōtl, candle.
kāmi'tqātlti'temōtl, hammer of gun.
k'tcē'ikā'tltliti'temōtl, map.
gitkā'tltliti'tɛmōtl, scissors.

The following list of derivatives from one radical will serve to show the power of word-formation which the language possesses, and the distinction which it is able to make between somewhat similar objects, while considering them all at bottom from the same fundamental root:—

From radical *k'tcōk* or *k'tsūk*, to pierce:
auger, *k'tcōktlā'ink·ō'mōtl*.
borer, *k'tsō'kōtl*.
fork, *k'tcū'kō'nē'mōtl*.
sword, *k'tsū'kōtē'yātl*.

DIALECTIC DIFFERENCES.

It can scarcely be said that there are two well-marked Kootenay 'dialects.' Considered in the light of the fact that the entire grammar of the two tribes is the same, such differences as do exist between the speech of the Upper and that of the Lower Kootenays might better be termed 'provincialisms.'

The peculiarities of the Lower Kootenay language as compared with the Upper Kootenay are as follows:—

I. *Phonetics.*—The Lower Kootenays speak more rapidly and have a tendency to syncopate words, which retain a purer form amongst the Upper Kootenays. This is seen in the words for *coat, leggings, skunk*. In some cases monosyllables with long vowels are produced by the contraction of dissyllables, *e.g.*, *tās – ta'qas* (enough). Certain vowel-substitutions are made. Thus, in all the Lower Kootenay words in which the suffix *-mē'yit* of the Upper Kootenay appears, it is uniformly pronounced *-mōyit* or *-mū'yit*. This *-mō'yit* is, however, occasionally heard amongst the Upper Kootenays. Another case of vowel difference is Upper Kootenay *ōpā't* = Lower Kootenay *ipā't* (white fish).

The *tl* (explosive *l*) of the Upper Kootenays is represented always in Lower Kootenay by *dl* (palatal-dorso-apical; *see* 'Report,' 1889, p. 802). Thus:—

Upper Kootenay.	Lower Kootenay.	English.
tlē'nē	*dlē'nē*	across
ōni'tlnē	*ōni'dlnē*	afraid (he is)
gō'tlwā	*gō'dlwā*	apple
āqk·ō'tlāk	*āqk·ō'dlāk*	beef
wisē'yātl	*wisē'yādl*	sweat-house

When the Lower Kootenay half-breeds speak Indian, they tend to make this *dl* a simple *l*. English half-breeds of the Upper Kootenay tend to make it *kl*, as do most Europeans trying to speak Kootenay.

II. *Grammar.*—The grammatical differences are few indeed. The persistence of the suffix *-nām* in *titk'ā'tɛnām* (man) and *pādlkē'nām* (woman) is worthy of note. The suffixes *-taiya* in *qāstaiya* (skunk), and *-nāk* in *mitski'kɛnāk* do not appear in these words in Upper Kootenay. In Upper Kootenay 'to do' is *kitki'nitl*, in Lower Kootenay *kiti'dlmādlki'nidl*, and the insertion of *-idlmādl-* continues throughout the conjugation of this verb in Lower Kootenay speech.

III. *Vocabulary.*—Some difference is caused by names of things which are not found in the Upper Kootenay region, trees, birds, and the like. There are, however, a number of words, *e.g.*, *blanket*, *fish*, *glove*, *goose*, *mallard*, *many*, *partridge*, *plate*, *sit down*, *silk*, *sleep*, *swallow*, which in Upper and Lower Kootenay are derived from two distinct roots, having no relation whatever to each other. Thus:—

English	Lower Kootenay	Root	Upper Kootenay	Root
blanket (my)	*gādlā'mādl*	*dlām*	*gācī't*	*cīt.*
fish	*äp*	*äp*	*gīāqkō*	?
glove	*pā'dlyā*	?	*āqkā'tl*	?
great	*nōdlā'nē*	*nō'dl-*	*witlkā'nē*	*witl-*
many	*wāiyē'nē*	*wāiyē-*	*yū'nōkā'nē*	*yū'nō-*

There are other differences caused by syncopation of words, as noted above. The cause of the differences between the speech of the Upper and that of the Lower Kootenays has not been explained. The writer believes this to be the first scientific record of them. The following word-list will be of interest:—

English	Upper Kootenay	Lower Kootenay
always	*ā'qkänmē'yit*	*ā'qkänmō'yit.*
bacon	*kyi'nūk'tsā'tla* (*i.e.*, pig)	*āqk'ō'tā'dl.*
bird	*tō'kutskä'mɛnē*	*tsinmi'nē.*
bird (species ?)	*tci'kɛmā'tlkō'ɛnkā'ɛk*	*tcik'kō'dlkō'ɛnkā'ɛk.*
bird (species ?)	*yi'kets'nā*	*yi'kets'nānō'qdlō* (whitey).
blanket (my)	*gā'cīt*	*gā-dlā'mādl.*
blanket-leggings (my)	*gā-kī'tektlū'kwā*	*gā'-kīdlū'kwā.*
climb (to—a tree)	*gō'wāha'kɛnō*	*gōwā'anu'kpōm.*
coat (my)	*gā-ka'tūū'mtlāɛt*	*gā-k'wū'mdlāɛt.*
creek (rivulus)	*ā'qkinnōqō'nūk*	*āqkä'minā.*
day-after-to-morrow	*tlō'nūkänmē'yit*	*dlō'nūkänmō'yit.*
evening-red	*ki'tɛnū'sitlmī'yit*	*ki'tɛnū'sidlmō'yit.*
few	*tcu'kōna'na*	*p'tca'kōna'na.*
fish	*gīā'kqō*	*äp.*
flap of tent	*gīātlāqa'nqōna'tl*	*gīhāt'mā'nqōnā'dl.*
glove (of buckskin)	*āqkā'tl*	*pā'dlyā.*
go away!	*ki'ntsnākē'tl*	*kintsnā'käntē'īkēdl.*
goose (wild, spec. ?)	*kāqū'tlō'k*	*mä'kāk.*
great (it is—)	*witlkā'nē*	*nōdlā'nē.*
grouse (ruffed)	*t'ā'nk'ūts*	*tāpi'sqō.*
hen	*gūtskā'k'minnū'k'mā'ɛnā*	*gākdli'dlinū'k'mā'ɛnā*
horse	*k'ā'tlaqā'ɛtltsin*	*gidlk'ā'dlaqā'ɛdltsin.*
kneel (to)	*qōā'nkänk'ā'mik*	*gō'āndlu'kpōm.*
make (to)	*kitki'nitl*	*kiti'dlmādlki'nidl.*
I make	*hō'nïtki'nē*	*hō'niti'dlmādlki'nē.*
mallard (duck)	*kä'nk'ūsknē'īkāk*	*mōp*; *mɛ'kāu.*
man	*titk'āt*	*titk'ā'tɛnām.*
many, plenty	*yū'nōkā'nē*	*wāiyē'nē.*
maple	*mitskik*	*mitski'kɛnā'k.*
midnight	*kā'iyāk'ā'wōk'tcitlmī'yit*	*kāiyāk'ā'wōk'tcidlmō'yit.*
moon	*k'tcitlmī'yitnatā'nik*	*k'tcidlmō'yitnatā'nik.*
morning (it is—)	*kä'nmēyi'tinē*	*kä'nmōyi'tinē.*
move (to)	*tlō'nkō*	*nō'kō.*
night	*k'tcitlmī'yit*	*k'tcidlmō'yit.*
plate (of tin)	*gōwū'mūqō*	*gā'känkē'kōk.*
quick!	*tsinā'kēn*	*tci'dlkā'tsē.*

English	Upper Kootenay	Lower Kootenay
rain (it rains)	*wā'tlūk'k·ō'k·ōi'tinē*	*ōkā'dlnīki'dlnē.*
sack	*ātsū'tlā*	*ā'tsūwā'dla.*
sit down	*yānk·ā'min*	*tsisä'k'nū.*
shoes (my moccasins)	*gā-tlā'ɛn*	*gā-dlū'mā.*
silk	*āqhitlu'ktcū*	*dlā'swā* [French *de la soie*].
skunk	*qā'qas*	*qāstai'yā.*
sky	*ā'qhitlmī'yit*	*ā'qkidlmō'yit.*
sleep (I—)	*hō'tsk'ōmnē''nē*	*hōtsnū'p'nē.*
he sleeps	*k'ōmnē''nē*	*nū'p'nē.*
we sleep	*hōtlk'ō'mnēnā'tlā*	*hōdlnūp'nā'dlā.*
sleep thou !	*k'ō'mnin*	*nū'pin.*
sleep ye !	*k'ōmnē'kētl*	*nū'pkēdl.*
swallow (*hirundo*)	*gī(y)ā'tlā*	*tcidl'ōk.*
to-day	*nāhō'sanmēyē'tkē*	*nāhō'sanmōyē'tkē.*
to-morrow	*känmē'yēt*	*känmō'yēt.*
white fish (species ?)	*ōpa't*	*ipā't.*
woman	*pā'tlkē*	*pādlkē'nām.*

The two tribes of the Kootenays, Upper and Lower, converse with each other with apparent ease, as each knows by heart most of the expressions which are different in the speech of each. Those Upper Kootenays who never visit the Lower Kootenay territory are very ignorant regarding this dialectic difference.

The result of our linguistic investigation has been to fix the place of the Kootenay thus :—

Ki'tōnā'qa, or Kootenay. An independent linguistic stock, with two dialects, differing slightly in phonetics, grammar, and vocabulary :—

A. Upper Kootenay.
B. Lower Kootenay.

KOOTENAY JARGON.

As usually happens where intercourse with the whites takes place, a jargon has sprung up, although its development has been hindered by the use of the widespread Chinook. Many of those who speak this 'Kootenay jargon' imagine they are acquainted with the real aboriginal tongue ; but it consists, in fact, of Kootenay words changed in form and sound to conform to English grammar and phonetics. A few examples will suffice to indicate its general character :—

Jargon	English	Kootenay
ka'tlahä'lcin	horse	*k'ātlaqā'ɛtltsin.*
ā'kiklä'c	house (his)	*ā'qkītlā'is.*
skä'taklēt	cold (it is)	*nisk'attlēē'tinē*
klō'klamā'ka	Stony Indians	*tlū'tlämā'ɛka.*
kā'mīnū'pqanē	see (I)	*hōnū'pqānē.*
sä'ntlōhō'n	sick (he is)	*sā'nitlqō'nē.*
ni'lkō	money	*ni'tlkō.*

By means of this jargon, which consists of a Kootenay vocabulary mutilated to suit European ideas of phonology and grammar, a number of the settlers manage to get along with the Indians, and to obtain a reputation for speaking the Kootenay language.

SLANG.

Amongst the young men of the Lower Kootenays a number of slang words are used, such as—

k'ā'dlā or *k'ɛ'dlā* = horse.
mi'stak'ɛ'dla = colt.

Colloquial expressions, which are not regarded as quite correct, are the following :—

tinā'mū, 'butter.'
ni'tlkō, 'bell.' Lit. 'iron, metal.'
tlāō'kwē, 'eleven.' For *ē'tūwōtlaō'kwē*. And so with 'twelve,' &c.
āqkink·ō'kō', 'match.' For *āqktē'mōtl*.
kitki'nk·ā, 'medicine man.' For *ni'pik·āk·ā'k·ā*.

PUNNING AND WORD-DISTORTION.

The Kootenay Indians are certainly acquainted with the art of punning, and the Indian A'mELū took great delight in repeating over and over again the distortions of certain words. Following examples will show the nature of these puns :—

For *pāpā*	he would say frequently	*pāpī'yā*.
„ *sāiwa'skō*	„ „	*sāuwa'tckō ; sāuwa'skō ; sā'iwasū'kw' ; sāuwasē'ko.*
For *g·ō'tcātc* (chipmunk)	„ „	*g·ōca'tckō ; g·ōtla'tskō.*

The Indians are very much amused at the mistakes made by whites in trying to learn their language, and laugh long and heartily at their expense. A few of these errors which came under the writer's notice might be chronicled here.

For *kānkū'ptcē*, 'bread baked in a frying-pan,' was said *tānkū'ptcē*, which reminded the Indians of *t'ānk·ūts*, 'grouse,' and set them in a roar of laughter. The same effect was produced by—

qū'qas, 'skunk,'	said for	*qū'qū*, 'crow.'
ā'qkām, 'pine,'	„	*A'qk'ām*, 'Fort Steele.'
ini'sin, 'horsefly,'	„	*ini'simin*, 'rainbow.'
k'ū'pī, 'owl,'	„	*k'ū'pōk*, 'woodpecker.'

Even the seemingly trifling mistake of saying *ā'qkōtla'kpēk'* for *ā'qkōtla'kpē'k*, 'leaf,' was provocative of much merriment.

BORROWED WORDS.

There appear to be but very few borrowed words in the Kootenay language. These are as far as ascertained—

From Nez Percé *suēapo*, Kootenay *sūyä'pī*, 'white man.'
„ ? Klikatat *nooksi*, 'otter,' Kootenay *na'ksak*, 'marten,' or *vice versâ*.
„ French *le capot*, Kootenay *tlī'kāpō'* (*dlī'kāpō'*), 'coat.'
„ Chinook jargon *Bo'stEn*, Kootenay *Bo'stEn*, 'American.'
„ „ „ *Kīndzâtc*, „ *Kindjâtc*, 'Canadian.'
„ French *de la soie*, Lower Kootenay *dlä'swā*, 'silk.'
„ a Salishan dialect, *stā'tlām*, canoe.

APPENDIX.

SHUSHWAPS. PHYSICAL CHARACTERISTICS.

The measurements of the three females here recorded were made at the mission of St. Eugène, where they were attending the mission school. The measurements of the Shushwap Antoine were made at the penitentiary of New Westminster, B.C., by Dr. F. Boas, and were kindly placed at the writer's disposal by him. From so few cases nothing absolute can be determined. The stature of the women resembles that of the Kootenay women, and the cephalic indices of the three individuals are practically identical 84 (or 82 on the skull), the index of the male being 82·9 (or 80·9 on the skull), all being brachycephalic. These data go towards strengthening the view that the Shushwaps resemble the coast tribes (*see* 'Report,' 1890, p. 632). The females belong to the colony of Shushwaps on the Columbia, within the Kootenay country.

—	Male	Female		
Number	1	1	2	3
Name	Antoine	Angélique	Amélie	Cecilia
Tribe	Shushwap (Kamloops)	Shushwap (Col. Lake)	(Sister of No. 1)	Shushwap (Col. Lake)
Age	22	10	17	17
	mm.	mm.	mm.	mm.
Height, standing	1,631	1,383	1,555	1,583
Height of shoulder	1,340	1,138	1,289	1,307
Height of point of second finger	594	534	580	591
Length of arm	746	604	709	716
Finger-reach	1,759	1,385	1,601	1,628
Height, sitting	877	751	810	834
Width of shoulders	375	314	355	357
Length of head	193	183	186	175
Breadth of head	160	154	156·5	147
Distance from root of nose to chin	126	110·5	117·5	112
Distance from root of nose to between lips	80	72	77	78
Width of face	150	130·5	136	140
Height of nose	53	55	54·5	52
Width of nose	39	40	33	34
Index of height of shoulder	82·2	82·3	82·9	82·6
Index of length of arm	45·7	43·7	46·7	45·2
Index of finger-reach	107·9	100·1	103·0	102·9
Index of height sitting	53·8	54·3	52·1	55·2
Index of width of shoulders	23·0	22·7	22·8	22·6
Cephalic index	82·9	84·3	84·0	84·0
Index of upper part of face	53·3	55·17	56·62	55·71
Index of face	84·0	84·67	86·39	80·00
Index of nose	77·1	72·72	60·55	65·38

Report of the Committee, consisting of Sir WILLIAM TURNER (*Chairman*), Mr. G. W. BLOXAM (*Secretary*), Sir WILLIAM H. FLOWER, Dr. J. G. GARSON, Mr. H. H. RISLEY, *and* Dr. E. B. TYLOR, *appointed to investigate the Habits, Customs, Physical Characteristics, and Religions of the Natives of India.* (*Drawn up by the Secretary.*)

DURING the past year Mr. Risley has published four volumes on the tribes and castes of Bengal. Two of these contain an ethnographic glossary and the other two the physical measurements of nearly 6,000

persons, representing eighty-nine of the leading castes and tribes of northern India, from the Bay of Bengal to the frontiers of Afghanistan.

The cost of this important work has been defrayed by the Indian Government, and the 'Official Edition,' from which this report has been compiled, has been circulated for criticism.

Through the agency of the district officers, supplemented by a good deal of personal inquiry and correspondence, Mr. Risley was enabled to secure the services of 190 correspondents scattered over every district of Bengal, and communicating in their turn with an indefinite number of representatives of the tribes and castes which formed the subjects of inquiry.

The measurements were taken almost entirely by three Indian gentlemen—two Hindoos and one Mahomedan—who had been instructed by Mr. Risley himself in the use of the instruments. The following observations were recorded: (1) Name of subject; (2) district of birth; (3) age; (4) nasal height; (5) nasal width; (6) bimalar breadth; (7) nasomalar breadth; (8) cephalic length; (9) cephalic breadth; (10) minimum frontal breadth; (11) minimum bizygomatic breadth; (12) height, vertex to intersuperciliary point; (13) height, vertex to tragus; (14) height, vertex to chin; (15) stature in cm.; (16) weight in grammes; (17) facial angle. The data thus obtained enable us to distinguish three types, called, by Mr. Risley, Aryan, Dravidian, and Mongoloid.

The Aryan type, as we find it in India at the present day, is marked by a relatively long (dolichocephalic) head; a straight, finely cut (leptorhine) nose; a long, symmetrically narrow face; a well-developed forehead, regular features, and a high facial angle. The stature is fairly high, ranging from 1,716 millimetres in the Sikhs of the Panjáb to 1,656 in the Brahmans of Bengal; and the general build of the figure is well-proportioned and slender rather than massive.

In the Dravidian type the form of the head usually inclines to be dolichocephalic, but all other characters present a marked contrast to the Aryan. The nose is thick and broad, and its index is higher than in any known race except the Negro. The facial angle is comparatively low; the lips are thick; the face wide and fleshy; the features coarse and irregular. The average stature ranges from 1,562 to 1,621 millimetres; the figure is squat and the limbs sturdy.

The Mongoloid type, which in some respects may be looked upon as intermediate between these two, while in other, and perhaps the most important, points it can hardly be deemed Indian at all, is found along the northern and eastern borders of Bengal. Its most prominent characters are a relatively short (brachycephalic) head; a broad face; a short, wide nose, very low in the bridge, and in extreme cases almost bridgeless; high and projecting cheekbones, and eyelids peculiarly formed so as to give the impression that the eyes are obliquely set in the head.

By applying to the entire series the nasal index, which Professors Flower and Topinard agree in regarding as the best of race distinctions, some remarkable results are arrived at. The average nasal proportions of the Málé Pahária, one of the most characteristic of the Dravidian tribes, are expressed by the figure 94·5, while the pastoral Gujars of the Panjáb have an index of 66·9, the Sikhs of 68·8, and the Bengal Brahmans and Kayasths of 70·4. In other words, the typical Dravidian, as represented by the Málé Pahária, has a nose as broad in proportion to

its length as the Negro, while this feature in the Aryan group can fairly bear comparison with the noses of sixty-eight Parisians, measured by Topinard, which gave an average of 69·4. Even more striking is the curiously close correspondence between the gradations of racial type indicated by the nasal index and certain of the social data ascertained by independent inquiry. If we take a series of castes in Bengal, Behar, or the North-Western Provinces, and arrange them in the order of the average nasal index, so that the caste with the finest nose shall be at the top, and that with the coarsest at the bottom of the list, it will be found that this order substantially corresponds with the accepted order of social precedence. The casteless tribes, Kols, Korwas, Mundas, and the like, who have not yet entered the Brahmanical system, occupy the lowest place in both series. Then come the vermin-eating Musahars and the leather-dressing Chamárs. The fisher castes of Bauri, Bind, and Kewat are a trifle higher in the scale; the pastoral Goala, the cultivating Kurmi, and a group of cognate castes from whose hands a Brahman may take water follow in due order, and from them we pass to the trading Khatris, the land-holding Bábhans, and the upper crust of Hindu society. Thus, it is scarcely a paradox to lay down as a law of the caste organisation in Eastern India that a man's social status varies in inverse ratio to the width of his nose. Nor is this the only point in which the two sets of observations—the social and the physical—bear out and illustrate each other. The character of the curious matrimonial groupings for which the late Mr. J. F. McLennan devised the happy term 'exogamous' also varies in a definite relation to the gradations of physical type. Within a certain range of nasal proportions, these subdivisions are based almost exclusively on the totem. Along with a somewhat finer form of nose, groups called after villages and larger territorial areas, or bearing the name of certain tribal or communal officials, begin to appear, and above these, again, we reach the eponymous saints and heroes, who in India, as in Greece and Rome, are associated with a certain stage of Aryan progress.

It deserves notice that the data obtained by the most modern anthropological method agree in the main not only with the long chain of Indian tradition, beginning with the Vedas and ending with the latest vernacular treatise on the theory and practice of caste, but also with the rationalised and critical story of the making of the Indian peoples, as it has been told by Sir William Hunter in the 'Imperial Gazetteer.' Here the historian shows how, through the veil of fable and miracle, in which prehistoric India is shrouded, traces may be discerned of a protracted struggle between a lower and a higher race, which would have tended to produce much the same results as our statistics bring out. Studied in the light of these statistics, it would seem that the standard Indian theory of caste may deserve more respectful consideration than has been accorded to it of late years.

The observations conducted by Mr. Risley include fifteen tribes and castes of Bengal Proper; five of the Chittagong Hills; ten of the Darjiling Hills; ten of Behar; seventeen of Chota Nagpur; twenty-three of the North-Western Provinces and Oudh; and nine of the Panjáb.

It is hoped that, within a reasonable time, the inquiry may be extended throughout the remainder of our Indian empire, and, with this object in view, your committee ask for reappointment, with a renewal of the grant.

Report of the Committee, consisting of Professor W. H. Flower (*Chairman*), Dr. J. G. Garson (*Secretary*), Mr. G. W. Bloxam, *and* Dr. Wilberforce Smith, *for the purpose of carrying on the work of the Anthropometric Laboratory.* (*Drawn up by* Dr. Garson, *Secretary.*)

The Committee have to report that at the Cardiff meeting of the Association last year excellent accommodation near the Reception-room was provided by the Local Committee for the Anthropometric Laboratory. The services of a clerk were, as previously, placed at the disposal of the Committee, and by the kind permission of Mr. Francis Galton, F.R.S., Sergeant Randall was again lent to your committee for the purpose of measuring the members of the Association who visited the laboratory. The Committee desire to express their high appreciation of Mr. Galton's assistance in thus from year to year closing his own laboratory at South Kensington during the meeting of the Association, so that Sergeant Randall may be able to give his time to the work of the laboratory of the Association, under the direction of Dr. Garson. Having the same measurer from year to year is of the utmost importance in securing uniformity of results, and will, it is hoped, make the collective statistics of several years' observations, when presented to the Association and published, of greater value than they would otherwise be.

The number of applicants for measurement was very often considerably greater than could be measured by the staff during the hours the laboratory was open. The Committee regret that members of the Association had often to wait, sometimes for a considerable time, before their turn for measurement came round, especially during the last few days of the meeting. To obviate this inconvenience as much as possible, it is desirable that those who intend to visit the laboratory next year should do so as early in the meeting as they can, since during part of the first and second days the laboratory is open it often happens that the staff is not fully occupied.

The schedule of measurements and observations which can best be made in the laboratory has now been fairly settled by experience of former years, so that there is no material change in it to mention in this report. The time which can be allotted to each candidate is necessarily limited, and it has been the aim of the Committee to select the measurements and observations which are of most importance and occupy least time, so as to obtain as much information as possible. To this circumstance must be attributed the absence of many tests, particularly those of a physiological nature, from the schedule, which might have been made had time not been an object of importance. The schedule includes the age, sex, birthplace, colour of eyes and hair, the profile of the nose, height when standing, sitting, and kneeling, vertical distance from the vertex to tragus, mouth, and chin, length and breadth of head, length and breadth of nose, length of cubit and of hand, span of arms, weight in ordinary clothing, strength of pull with each hand, vital capacity of lungs, strength of vision with each eye and sense of colour, and in males the maximum and minimum circumference of the chest during inspiration and expiration respec-

tively. A duplicate of the schedule with the measurements recorded on it is handed to each person measured. The metric system is used, and all measurements *are expressed in millimetres* except the weight, pull, and vital capacity of lungs, which are given in pounds and cubic inches, owing to the instruments not being graduated to kilogrammes and cubic centimetres. The total number of persons measured during the Cardiff meeting was 103, of whom 73 were males and 30 were females. This is somewhat fewer than during the previous meeting, and is partly to be accounted for by the fact that during the first few days of the meeting comparatively few persons visited the laboratory, although towards the end there was far more work to do than could be got through. The meeting was also a small one, and the weather was exceedingly bad.

Since the close of the meeting the statistics of the observations then made have been carefully worked up under the direction of the Secretary after the plan which has been adopted in dealing with those of former years, and are as follows :—

Age.—The males examined varied in age from 18 to 69 years. Of these only 3 were 18 and under 20 years, 15 between 20 and 30 years, 23 between 30 and 40 years, 17 between 40 and 50 years, 11 between 50 and 60 years, and 4 between 60 and 70 years. Of the females 2 were under 18 years of age, and are not included in the statistics, 2 were between 18 and 20 years, 10 between 20 and 30 years, 7 between 30 and 40 years, 4 between 40 and 50 years, 4 between 50 and 60 years, and 1 between 60 and 70 years.

Birthplace and Residence.—Only 18, that is about 25 per cent. of the males, and 10, that is 33 per cent. of the females, were born in or near Cardiff, or are Welsh by birth. The remainder of both sexes came from various parts of England, Scotland, and Ireland, the percentages from each place being small, on account of the number of counties represented. As regards residence the number of dwellers in large towns and the country were about equal in number.

Occupation.—The larger proportion of the males measured were professional men ; the minority were engaged in commercial pursuits.

Colour of Eyes.—The colour of the eyes was tested with Mr. F. Galton's set of standards—light, medium, and dark in colour. According to this scale 43·9 per cent. of the males were light-eyed, 27·3 per cent. medium or of grey colour, and 28·8 per cent. were dark-coloured, including the various shades of brown. Of the females 10 had light eyes, 8 medium, and 9 dark eyes out of 27. On account of the smallness of the numbers the latter have not been reduced to percentages.

Colour of Hair.—Dividing the hair into the classes of dark, medium, and light, with special classes, if required, for red and albino, and omitting all cases of grey hair due to senile changes, 48·2 of the males had light hair, 11·1 had medium, and 40·7 per cent. had dark hair. As there was no standard to give to the observer of the limits of each class the figures just given are his own ideas as to the different shades, and it is evident that many cases of medium-coloured hair have been included amongst the light-haired group. For this reason comparison of the frequency of the various combinations of colour of eyes and hair has not been attempted. This defect in the observations on the colour of the hair will be remedied in future, as the standards of eyes and hair have since the last meeting of the Association been published in the new edition of 'Notes and Queries on Anthropology.'

Profile of Nose.—The outline in profile of the nose has been recorded, according to Broca and Topinard's standards, published on plate iv. opposite page 20 in the second edition of 'Notes and Queries on Anthropology' just referred to. The straight form (fig. 1) greatly predominates, but the hooked form (fig. 3) is also met with. As it appears uncertain whether or not a little confusion has arisen in some of the forms, further analysis is omitted.

Height.—For the sake of convenience persons were measured with their boots or shoes on their feet, but to ascertain their actual height the thickness of the heels was also measured and subtracted from the total indicated height.

The stature of the males at the 25th grade is 1,688, at the 50th 1,740; and at the 75th, 1,774; the 'Q' or half the difference between the stature at the 25th and 75th grades is 43 mm., giving a corrected mean stature of 1,731. The stature of the females is at the 25th grade 1,562; at the 50th, 1,612; and at the 75th, 1,662; 'Q' is therefore 50, making the corrected mean 1,612.

Height when Sitting.—This measurement gives the length of the head, neck, and trunk of the body. In the males, at the 25th grade, it is 886; at the 50th, 913; at the 75th, 934; 'Q' is 23, making the corrected mean 910. In the females it is at the 25th grade 825; at the 50th, 867; at the 75th, 888; 'Q' is 31, and the corrected mean 856.

Length of Lower Limbs.—When the height sitting is subtracted from the standing height the difference indicates the amount contributed to the stature by the lower limbs. In the males this is at the 25th grade 801; at the 50th, 826; at the 75th, 840; the corrected mean is therefore 820. In the females it is at the 25th grade 737; at the 50th, 745; at the 75th, 774; and the corrected mean is 756.

Length of Leg and Height of Foot.—This is obtained by subtracting the kneeling height from the standing height. The latter is at the 25th grade 1,262; at the 50th, 1,303; at the 75th, 1,328; 'Q' equals 33, and the corrected mean, 1295. Subtracting these figures from the corresponding figures of the standing height previously given we find the length at the 25th grade is 426; at the 50th, 436; at the 75th, 446; 'Q' equals 10, and the corrected mean 436 in the males.

In the females the kneeling height is at the 25th grade 1,175; at the 50th, 1,225; at the 75th, 1,262; 'Q' equals 43, and the corrected mean 1,218. The length of the leg and foot portion of the limb in the females is therefore at the 25th grade 387; at the 50th, 387; at the 75th, 401; 'Q' equals 6·6, and the corrected mean 394. This case illustrates the advantage of using the corrected mean as well as the calculated mean. It will be observed that the latter is considerably higher in the kneeling height than the former; hence in the length of the lower segment of the limb the length at the 25th and 50th places is the same, which is not the case, and what it should be is shown by the corrected mean. No doubt this anomalous condition arises in part from the small number of females measured, and in part from the fact that the estimate has been made by subtraction and not by actual calculation from the figures themselves.

Length of Thigh Portion of the Lower Limb.—This is ascertained by subtracting the length of the leg and foot portion from the total length of the limb. In the males it is at the 25th grade 375; at the 50th, 390; at the 75th, 394; 'Q' equals 7, and the corrected mean is 384. In the

females at the 25th grade it is 350; at the 50th, 358; at the 75th, 373; 'Q' equals 11, and the corrected mean is 361.

The corrected mean stature of the males is made up, according to the foregoing figures, by the different parts of the body in the following proportions: The head, neck, and trunk contribute 52·6 per cent., the thigh from the lower level of the tuber ischia to the knee 22·2 per cent., and the leg and height of the foot 25·2 per cent. In the females the head, neck, and trunk form 51·3, the thigh 22·4, and the leg and height of the foot 24·5 per cent. of the mean corrected stature.

Vertical Projection of the Head.—This is the vertical distance from the vertex to the under surface of the chin. In the males it is at the 25th grade 206; at the 50th, 214; at the 75th, 222; 'Q' equals 8, making the corrected mean 214. The vertical projection of the head contributes 12·4 per cent. of the corrected mean stature of the body. In the females the mode of dressing the hair has so much interfered with the results that they would appear to have longer heads than the males, and have consequently been omitted.

Distance from Vertex to Mouth.—In the males it is at the 25th grade 156; at the 50th, 165; at the 75th, 172; 'Q' equals 8, and the corrected mean 164. The vertex to the mouth contributes 76·8, and the chin 23·2 per cent. to the total projection of the head.

Distance from Vertex to Tragus.—This represents, as far as is possible on the living, the height of the head. In the males it is at the 25th grade 124; at the 50th, 130; at the 75th, 133; 'Q' equals 4, and the corrected mean 128. Owing to the uncertainty of the results the females are omitted.

Length of Head.—In the males at the 25th grade it is 195; at the 50th, 199; at the 75th, 203; 'Q' is 4, and the corrected mean 199. In the females it is at the 25th grade 186; at the 50th, 189; at the 75th, 192; 'Q' is 3, and the corrected mean 189.

Breadth of Head.—In the males it is at the 25th grade 152; at the 50th, 156; at the 75th, 160; 'Q' is 4, and the corrected mean 156. In the females it is at the 25th grade 145; at the 50th, 148; at the 75th, 150; 'Q' is 2·5, and the corrected mean 147·5.

Proportions of the Head.—The cephalic index in the males varies from 71 to 91; at the 25th grade it is 76·6; at the 50th, 78·5; at the 75th, 79·9; 'Q' is 1·6, and the corrected mean is 78·3. It will be seen from this that the 25th and 75th grades lie in the mesaticephalic group. According to the international division of the cephalic index on the skull, 8 of the series are dolichocephalic, 44 are mesaticephalic, 19 are brachycephalic, 1 is hyperbrachycephalic, and 1 is ultrabrachycephalic. In the females the cephalic index varies from 73 to 84; at the 25th grade it is 76·5; at the 50th, 78·5; at the 75th, 80; 'Q' is 1·7, and the corrected mean 78·2. The index in the two sexes at the different grades agrees very closely. By the international division 2 of the females are dolichocephalic, 18 are mesaticephalic, and 8 are brachycephalic. There is thus less variation in the form of their heads than in the males. The height-length index in the males is 64·5, taken from the corrected mean measurements of length and projection from vertex to tragus. The module of the head, obtained by adding the length, breadth, and height together, adding to their product 15 in the case of males and 13 for females, and dividing the whole sum by 3, is, in the males, at the 25th grade, 157·9; at the 50th, 161·4; at the 75th, 165·2; 'Q' is 3·6, and

the corrected mean is 161·5. The index of the relative proportion which the length of the head from the glabella to the occiput bears to the length from the vertex to the chin (the latter being taken as 100) is 93 ; that of the breadth to the vertical projection of the head is 72·9 in the males. If the glabello-occipital length is taken as 100, the index it forms with the total projection of the head is 107·5.

Nasal Index.—In the males the nasal index is 56·5 at the 25th grade ; at the 50th, 60·3 ; at the 75th, 64·8 ; 'Q' is 4·1, and the corrected mean 60·6. In the females it is at the 25th grade 55·1 ; at the 50th, 55·9 ; at the 75th, 56·6 ; 'Q' is ·7, and the corrected mean is therefore 55·8. The index ranges in the males from 48·2 to 86·6, and from 49 to 66·6 in the females.

Face Index.—In the males the facial index is at the 25th grade 105 ; at the 50th, 110 ; at the 75th, 119 ; 'Q' equals 7, and the corrected mean 112. In the females it is at the 25th grade 106 ; at the 50th, 114 ; at the 75th, 118 ; 'Q' equals 6, and the corrected mean 112. This index is calculated from the bizygomatic breadth and nasio-mental length of the face, the latter being taken as 100.

Length of Cubit.—In the males the length of cubit at the 25th grade is 452 ; at the 50th, 464·7 ; at the 75th, 478 ; 'Q' equals 13, and the corrected mean is 465. The corrected mean length of cubit is 26·8 per cent. of the corrected mean stature. In the females the length of the cubit at the 25th grade is 404 ; at the 50th, 419 ; at the 75th, 431 ; 'Q' equals 14, and the corrected mean is 417. The cubit in them is 25·9 of the stature.

Length of Hand (right).—In the males the length of the right hand at the 25th grade is 186·6 ; at the 50th, 192·6 ; at the 75th, 199·6 ; 'Q' equals 6·5, and the corrected mean 193. The corrected mean length of hand is 11·1 per cent. of the corrected mean stature. In the females the length of hand at the 25th grade is 170 ; at the 50th, 177·8 ; at the 75th, 184·2 ; 'Q' is 6·6, and the corrected mean 177·6, or 11·0 per cent. of the corrected mean stature ; in the males the 41·5 per cent. of the cubit, and in the females 42·5 per cent. Subtracting the corrected mean length of the hand from the corresponding length of the cubit, the mean length of the forearm proper is 272 in the males and 239 in the females ; the length of the hand is to that of the forearm in the former as 71, and in the latter as 74·3 to 100.

Span of Arms.—In the males the span of the arms varies from 1,575 to 1,900 ; at the 25th grade it is 1,738 ; at the 50th, 1,771 ; at the 75th, 1,814 ; 'Q' is 38, and the corrected mean is 1,776. In the females it is at the 25th grade 1,550 ; at the 50th, 1,601 ; at the 75th, 1,644 ; 'Q' equals 47, and the corrected mean is 1,597. The proportion which the span bears to the stature (the latter being taken as 100) is in the males as 102·6, and in the females 105·2. The span of the arms exceeds the stature in 10 cases out of 70 in the males, and in 13 out of 26 in the females, or in 14·3 per cent. of the former, and in 50 per cent. of the latter.

Weight.—In the males the weight at the 25th grade is 144 lbs. ; at the 50th, 162·5 lbs. ; at the 75th, 167 lbs. ; 'Q' equals 11·6, and the corrected mean is 156 lbs., or 11 st. 2 lbs. In the females it is at the 25th grade 116·7 lbs. ; at the 50th, 122·5 lbs. ; and at the 75th, 131·7 lbs. ; 'Q' equals 7·5, and the corrected mean is 124·2 lbs., or 8 st. 12 lbs., that is, 2 st. 4 lbs. less than the males.

Pull.—The mean strength of pull of both hands is in the males at the 25th grade 60·8 lbs.; at the 50th, 68·4; at the 75th, 74·9; 'Q' is 7, and the corrected mean is 67·8 lbs. In the females it is at the 25th grade 32 lbs.; at the 50th, 36; at the 75th, 43·3; 'Q' equals 5·6, and the corrected mean is 37·6 lbs. In 32 cases out of 71 in the males the pull with the right hand is the stronger, in 33 the left is the stronger, and in 6 cases the two hands are of equal strength. In 27 females the right hand is the stronger in 9 cases, the left in 14, and in 6 the two hands are equal.

Vital Capacity of Lungs.—In the males the vital capacity at the 25th grade is 188 cubic inches; at the 50th, 221 cubic inches; at the 75th, 254·5 cubic inches; 'Q' equals 33·2, and the corrected mean is 221·2 cubic inches. In the females it is at the 25th grade 101·4; at the 50th, 125·5; at the 75th, 148·8 cubic inches; 'Q' equals 23·4, and the corrected mean is 124·8 cubic inches. The vital capacity of the chest was ascertained by means of Stanley's spirometer, kindly lent for the meeting by the manufacturers, Messrs. Tallack & Co., of 28 Hatton Garden, London, to whom the Committee express best thanks for having placed at their disposal, for two consecutive years, this very excellent instrument.

Circumference of the Chest.—This dimension was only ascertained on the males. At the 25th grade, during forced inspiration, it measures 932 millimetres; at the 50th, 970 millimetres; at the 75th, 1,017 millimetres; 'Q' equals 42, and the corrected mean 976 millimetres. The difference between forced inspiration and forced expiration is at the 25th grade 41 millimetres; at the 50th, 52 millimetres; at the 75th, 69 millimetres; 'Q' is 14, and the corrected mean 55 millimetres. By subtracting half of this latter sum from the corrected mean circumference of the chest during forced inspiration, we get 968 millimetres as the girth of the chest when the lungs are midway between forced inspiration and expiration.

Vision.—The power of vision was tested with Snellen's test-types placed at a distance of 6 metres from the eye. The number of males who could read No. 6 type with both eyes (each eye being tested separately) was 38 out of 73, that is 52 per cent., and 14 of these were able to read No. 5 at 6 metres. Of the females 13 out of 26, or 50 per cent., had normal vision; that is to say were able to read No. 6 test-type at 6 metres; indeed, all but 4 of them were able to read No. 5 at 6 metres. In several cases the vision with one eye was normal, while that of the other was more or less defective. The time which could be devoted to each candidate was too short to permit of any investigation as to the cause of the deficiencies in vision being undertaken.

Colour Sense.—This was tested by asking the candidate to pick out first the greens and afterwards the reds from a series of cards which contained the various confusion colours for green and red blindness, and several other colours. Three of the males were found to be colour-blind.

For purposes of comparison a table of the corrected means of the different measurements dealt with in this report has been made out, and placed side by side with the corresponding figures obtained from the laboratory in the previous year.

The Committee desire to be reappointed, and to have a sum of 5*l.* again placed at their disposal.

Table of Measurements of Males.

—	1891. Cardiff. Number, 73	1890. Leeds. Number, 95
Stature	1,731 mm.	1,720 mm.
Sitting Height	910 „	911 „
Length of Thigh	384 „	377 „
Length of Leg	436 „	431 „
Vertical Projection of Head (vertex to chin)	214 „	213 „
Height of Head (vertex to tragus)	128 „	—
Length of Head	199 „	189 „
Breadth of Head	156 „	155 „
Cephalic Index	*78·3*	*78·*
Module of Head	166 mm.	160 mm.
Nasal Index	*60·6*	*65·*
Face Index	112 mm.	112 mm.
Length of Cubit	465 „	464 „
Length of Hand	193 „	—
Span of Arms	1,776 „	1,769 „
Weight	156 lbs.	155½ lbs.
Mean Pull	67·8 „	65 „
Vital Capacity of Lungs, cubic inches	221 cub. in.	217 cub. in.
Maximum Circumference of Chest	976 mm.	—

TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—Professor Arthur Schuster, Ph.D., F.R.S., F.R.A.S.

THURSDAY, AUGUST 4.

The President delivered the following Address:—

In opening the proceedings of our annual meeting the temptation is great to look back on the year which has passed and to select for special consideration such work published during its course as may seem to be of the greatest importance. I fear, however, that a year is too short a time to allow us to form a fair estimate of the value of a scientific investigation. The mushroom, which shoots up quickly, only to disappear again, impresses us more than the slow-growing seedling which will live to be a tree, and it is difficult to recognise the scientific fungus in its early stage. But, although I do not feel competent to give you a review of the progress made in our subject during the last twelve months, there is one event to which some allusion should be made. It has been the sad duty of many of my predecessors to announce the death of successful workers in the field of science, but I believe I am unique in having the pleasure of recording the birth of a scientific man. At the beginning of this year there came into the world a being so brilliant that he could, without preparation, take up the work of the most eminent man amongst us. Believers in the transmigration of souls have speculated on the fact that Galileo's death and Newton's birth fell within a year of each other; but no event has ever happened so striking as that which took place on the 1st of January, when the mantle of Sir William Thomson fell on the infant Lord Kelvin. Those who have attended these meetings will feel with me that the honour done to our foremost representative, an honour which has been a source of pride and satisfaction to every student of science, could not altogether remain unnoticed in the section which owes him so much.

We are chiefly concerned here with the increase of scientific knowledge, and we derive pleasure in contrasting the minor state of ignorance of our own time with that which prevailed a hundred years ago. But when we contrast at the same time the refined opportunities of a modern research laboratory with the crude conditions under which the experimentalist had to work at the beginning of the century, we may fairly ask ourselves whether it is possible by means of any systematic course of study or by means of any organisation to accelerate our progress into the dark continent of science. A number of serious considerations arise in connection with this subject, and though I am not going to weary you by attempting an exhaustive discussion, I should like to draw your attention to a few matters which seem to me to be well worthy of the consideration of this Association. Changes are constantly made or proposed in our existing institutions,

and new ones are suggested which are to serve the purpose of a more rapid accumulation of knowledge. I need only allude to the alterations in the curriculum of the science schools in our old Universities, made partly for the purpose of fitting their graduates for the conduct of original research, or to the national laboratory proposed by my predecessor in this chair for carrying out a certain kind of scientific investigation, which at present is left undone, or is done by private enterprise. Even our own Association has not escaped the evil eye of the reformer, and, like other institutions, it may be capable of improvement. But in choosing the direction in which a change may best be made, I think we may learn something from the way in which Nature improves its organisms. We are taught by biologists that natural selection acts by developing those qualities which enable each species best to survive the struggle for existence; useless organs die off or become rudimentary. Nature teaches us, therefore, how a beautiful complex of beings, mutually dependent on each other, is formed by improving those parts which are best and most useful, and letting the rest take care of itself. But in many of the changes which have been made or are proposed the process of reform is very different. The weakest points are selected, our attention is drawn to some failure or to something in which we are excelled by other nations, and attempts are made to cure what perhaps had better be left to become rudimentary. The proceeding is not objectionable as long as the nourishment which is applied to develop the weaker organs is not taken from those parts which we should specially take care to preserve. To apply these reflections to the question with which we are specially concerned, I should like to see it more generally recognised that although there is no struggle for existence between different nations, yet each nation, owing to a number of circumstances, possesses its own peculiarities, which render it better fitted than its neighbours to do some particular part of the work on which the progress of science depends. No country, for instance, has rivalled France in the domain of accurate measurement, with which the names of Regnault and Amagat are associated, and the International Bureau of Weights and Measures has its fitting home in Paris.[1] The best work of the German Universities seems to me to consist in the following up of some theory to its logical conclusions and submitting it to the test of experiment. I doubt whether the efforts to transplant the research work of German Universities into this country will prove successful. Does it not seem well to let each country take that share of work for which the natural growth of its character and of its educational establishments best adapts it? Is it wise to remedy some weak point, to fill up undoubted gaps, if the soil that fills the gaps has to be taken from the hills and elevations which rise above the surrounding level?

As far as the work of this section is concerned the strongest domain of this country has been that of mathematical physics. But it is not to this that I wish specially to refer. Look at the work done in Great Britain during the last two centuries; the work not only in physics, but in astronomy, chemistry, biology. Is it not true that the one distinctive feature which separates this from all other countries in the world is the prominent part played by the scientific amateur, and is it not also true that our modern system of education tends to destroy the amateur?

By amateur I do not necessarily mean a man who has other occupations and only takes up science in his leisure hours, but rather one who has had no academical training in that branch of knowledge which he finally selects for study. He has probably been brought up for some profession unconnected with science, and only begins his study when his mind is sufficiently matured to form an entirely unbiassed opinion. We may, perhaps, best define an amateur as one who learns his science as he wants it and when he wants it. I should call Faraday an amateur. He would have been impossible in another country; perhaps he would be impos-

[1] Much of the good work done by this Bureau remains unknown, owing to the miserly way in which their publications are circulated. No copies are supplied even to the University libraries. The explanation, of course, is 'want of funds.' In other words, England, France, and Germany, together with other nations, unite to do a certain kind of work, but cannot afford to distribute a few copies of the publication to the public for whose benefit the work is undertaken.

sible in the days of the Science and Art Department. Other names will occur to you, the most typical and eminent being that of Joule. It is not my purpose to discuss why distinguished amateurs have been so numerous in this country, but I am anxious to point out that we are in danger of losing one great and necessary factor in the origination of scientific ideas.

One of the distinctive features of an amateur is this, that he carries not the weight of theories, often not the weight of knowledge, and, if I am right, there is a distinct advantage in having one section of scientific men beginning their work untrammelled by preconceived notions, which a systematic training in science is bound to instil. Whatever is taught in early years must necessarily be taught in a more or less dogmatic manner, and, in whatever way it is taught, experience shows that it is nearly always received in a dogmatic spirit. It seems important, therefore, to confine the early training to those subjects in which preconceived notions are considered an advantage. It is to me an uncongenial task to sound a note of warning to our old Universities, for the chief difficulties in which they are placed at present are due to the fact that they have given way too much to outside advice; but I cannot help expressing a strong conviction that their highly specialised examinations for entrance scholarships are a curse to all sound school education, and will prove a still more fatal curse to what concerns us most nearly, the progress of scientific knowledge. If school education could be more general, if scientific theories could only be taught at an age when a man is able to form an independent judgment, there might be some hope of retaining that originality of ideas which has been a distinctive feature of this country, and enabled our amateurs to hold a prominent position in the history of science. At present a knowledge of scientific theories seems to me to kill all knowledge of scientific facts.

It is by no means true that a complete knowledge of everything that has a bearing on a particular subject is always necessary to success in an original investigation. In many cases such knowledge is essential, in others it is a hindrance. Different types of men incline to different types of research, and it is well to preserve the dual struggle. The engine which works out the great problems of nature may be likened to a thermodynamic machine. The amateur supplies the steam and the Universities supply the cold water; the former, boiling over often with ill-considered and fanciful ideas, does not like the icy bath, and the professional scientist rebels against the latent heat of the condensing steam, but nevertheless the hotter the steam and the colder the water the better works the machine. Sometimes it happens that boiler and cooler are both contained in the same brain, and each country can boast of a few such in a century, but most of us have to remain satisfied with forming only an incomplete part of the engine of research.

But while it is necessary to recognise the great work done by the amateur, it seems not untimely to draw their attention to the damage done to themselves if they overstep their legitimate boundaries, and especially if they seek popular support for such of their theories as have not received the approval of those who are competent to judge. An appeal from Philip sober to Philip drunk will not prove successful in the end.

The gradual disappearance of the amateur may be a necessary consequence of our increased educational facilities, and we must inquire whether any marked advantages are offered to us in exchange. There is one direction in which it would seem at first sight, at any rate, that a proper course of study could do much to facilitate the progress of research.

On another occasion I pointed out that two parties are necessary for every advance in science, the one that makes it and the one that believes in it. If the discoverer is born, and cannot be made, would it not be possible to train the judgment of our students so that they may form a sound opinion on the new theories and ideas which are presented to them? It is too early as yet to judge in how far our generation is better in this respect than the one that has gone before it, but on closer examination it does not seem to me to be obvious that any marked improvement is possible. Every new idea revolutionising our opinions on some important question must necessarily take time before it obtains a proper hold on the scientific world. Is it not true that anyone who can at once see the full

importance of a new theory, and accept it in place of the one in which he has been brought up, must stand at a height almost equal to that of the originator? The more startling and fresh the new conception the fewer must be those who are ready to adopt it. But looking back at the history of science during the present century, is there much evidence that great discoveries have been seriously delayed by want of proper appreciation? We may hear of cases where important papers have been rejected by scientific societies, and occasionally a man of novel ideas may have been too much neglected by his contemporaries. I doubt whether such cases of apparent injustice can ever be avoided, and, considering the great changes involved in matters of primary importance, such as the undulatory theory of light, the conservation of energy, and the second law of thermodynamics, I cannot admit that there is much reason to be dissatisfied with the rate at which new theories have been received. Those who experience a temporary check, owing to the fact that public opinion is not ripe for their ideas, are often fully rewarded after the lapse of a few years. The disappointment which Joule may have felt during the time his views met with adverse criticisms from the official world of science was no doubt amply compensated by the pleasure with which he watched the subsequent progress of research in the new domain which his discoveries have opened out.

The point is not one of academic interest only, for the fear of repressing some important new discovery has a disastrous influence in another direction. The judgment of the scientific world seems to me to be tending too much towards leniency to apparently absurd theories, because there is a remote chance that they may contain some germ of real value. A new truth will not be found to suffer ultimately by adverse and even unreasonable criticism, while bad theories and bad reasoning, supported by the benevolent neutrality of those to whose judgment the scientific world looks for guidance, are harmful in many ways. They block the way to an independent advance and encourage hasty and ill-considered generalisations. The conclusion I should draw from the considerations I have placed before you are these: I believe that a reasonable censorship exercised by our scientific societies is good and necessary; that those whose fate it is to be called on to express an opinion on some work or theory should do so fearlessly according to their best judgment. Their opinion may be warped by prejudice, but I think it is better that they should incur the risk of being ultimately found to be wrong than that they should help in the propagation of bad reasoning. There is one matter, however, on which all opinions must agree. Worse than bad theory or logic is bad experimental work. Should we then not rigorously preserve any influence or incentive which encourages the beginner to avoid carelessness and to consider neither time nor trouble to secure accuracy? There is no doubt to my mind that the prospect of admission to the Royal Society has been most beneficial in this respect, and that the honourable ambition to see his paper published in the 'Transactions' of that society has preserved many a student from the premature publication of unfinished work.

One of the principal obstacles to the rapid diffusion of a new idea lies in the difficulty of finding suitable expressions to convey its essential point to other minds. Words may have to be strained into a new sense, and scientific controversies constantly resolve themselves into differences about the meaning of words. On the other hand, a happy nomenclature has sometimes been more powerful than rigorous logic in causing a new train of thought to be quickly and generally accepted.

A good example is furnished by the history of the science of energy. The principle of the conservation of energy has undoubtedly gained, by the introduction of the term 'potential energy,' a more rapid and general acceptance than it would otherwise have received. A great theorem, which in itself seems to me to be an intricate one, has been simplified by calling something energy which, in the first place, is only a deficiency of kinetic energy. The only record I can find on the history of the expression is given in Tait's 'Thermodynamics,' wherein the term 'statical energy' is ascribed to Lord Kelvin, and that of 'potential energy' to Rankine. It would be of interest to have a more detailed account on the origin of

an expression which has undoubtedly had a marked influence, not only on the physics, but also on the metaphysics of our time. But while fully recognising the very great advantage we have derived from this term 'potential energy,' we ought not, at the same time, to lose sight of the fact that it implies something more than can be said to be proved. It is easy to overstep the legitimate use of the word. Thus, when Professor Lodge[1] attempts to prove that action at a distance is not consistent with the doctrine of energy, he cannot, in my opinion, justify his position except by assuming that all energy is ultimately kinetic. That is a plausible but by no means a necessary theory. Efforts have been made to look on energy as on something which can be labelled and identified through its various transformations. Thus we may feel a certain bit of energy radiating from a coal-fire, and if our knowledge was complete, we ought to be able to fix the time at which that identical bit of energy left the sun and arrived on the surface of the earth, setting up a chemical action in the leaves of the plant from which the coal has been derived. If we push this view to a logical conclusion, it seems to me that we must finally arrive at an atomic conception of energy which some may consider an absurdity.

Let, for instance, a number of particles P_1, P_2, &c., in succession, strike another particle, Q. How can we in the translatory energy of the latter identify the parts which P_1, P_2, &c., have contributed? According to Professor Lodge's view, we should be able to do so, for if the particle Q in its turn gives up its energy to others, say R_1, R_2, R_3, &c., we ought to be able to say whether the energy of P_1 has ultimately gone into R_1 or into R_2, or is divided between them. It is only by imagining that all energy is made up of a finite number of bits, which pass from one body to another, that we can defend the idea of considering energy as capable of being 'labelled.'

In the expressions we adopt to describe physical phenomena we necessarily hover between two extremes. We either have to choose a word which implies more than we can prove, or we have to use vague and general terms which hide the essential point, instead of bringing it out. The history of electrical theories furnishes a good example. The terms positive and negative electricity committed us to something definite; we could reckon about quantities of electricity, and form some definite notion of electrical currents as a motion of the two kinds of electricity in opposite directions. Now we have changed all that; we speak of electric displacements, but safeguard ourselves by saying that a displacement only means a vector quantity, and not necessarily an actual displacement. We speak of lines and tubes of force not only as a help to realise more clearly certain analytical results, but as implying a physical theory which, at the same time, does not commit us to anything. I do not find any fault with this, for it is a perfectly legitimate and necessary process to state the known connection between physical phenomena in some form which introduces the smallest number of assumptions. But the great question, 'What is electricity?' is not touched by these general considerations. The brilliant success with which Maxwell's investigations have been crowned is apt to make us overrate the progress made in the solution of that question. Maxwell and his followers have proved the important fact that optical and electrical actions are transmitted by means of the same medium. We may be said to have arrived in the subject of electricity at the stage in which optics was placed before Young and Fresnel hit on the idea of transverse vibrations, but there is no theory of electricity in the sense in which there is an elastic solid theory of light.

If the term electrical displacement was taken in its literal sense, it would mean that the electric current consists of the motion of the ether through the conductor. This is a plausible hypothesis, and one respecting which we may obtain experimental evidence. The experiments of Rayleigh and others have shown that the velocity of light in an electrolyte, through which an electric current is passing, is, within experimental limits, the same with and against the current. This result shows that if an electrical current means a motion of the ether the velocity of the medium

[1] *Phil. Mag.*, vol. xi. 1881, p. 36.

cannot exceed ten metres a second for a current density of one ampère per square centimetre. This, then, is the upper limit for a possible velocity of the medium. Can we find a lower limit? The answer to that question depends on the interpretation of a well-known experiment of Fizeau's, who found that the speed of light is increased if it travels through water which moves in the same direction as the light. If this experiment implies that the water carries the ether with it, and if a motion of the ether means an electric current, we should be led to the conclusion that a current of water should deflect a magnet in its neighbourhood. An experiment made to that effect would almost certainly give a negative result, and would give us a lower limit for the velocity of the medium corresponding to a given current. Such an experiment, together with that of Rayleigh, would probably dispose of the theory that an electric current is due to a translatory velocity of the medium. This would be an important step, and it would be worth while to arrive at a final settlement of the matter.[1] The whole question of the relation between the motion of matter and motion of the medium is a vital one, and we shall probably not make any serious advances until experiment has found a new opening. But we must expect many negative results before some clue is discovered. Nor can we attach much importance to negative results unless they are made by someone in whose care and judgment we place full reliance. We should all the more, therefore, recognise the courage and perseverance of those who spend their valuable time in such investigations as Professor Lodge has recently undertaken. That ultimately some relation will be found between moving matter and electrical action there is no reasonable doubt.

One of the most hopeful openings for new investigations has always been found in the pursuing of a theory to its logical conclusions, and there is one result of the electromagnetic theory of light which has not, in my opinion, received the share of attention which it deserves.

When sound passes through air it is propagated more quickly with the wind than against it, and we may easily find the velocity relative to the earth by combining the ordinary sound velocity with the velocity of the wind. Similarly, when any waves pass through a medium moving with uniform velocity, the waves being due to internal stresses in the medium, we may treat of the velocity of the waves independently of that of the medium, and say that the wave-velocity in the direction of motion of the medium, and relative to a fixed body, is the sum of the wave-velocity calculated on the supposition that the medium is at rest and the velocity of the medium. Professor J. J. Thomson,[2] applying Maxwell's equations, has arrived at a different result for electromagnetic waves, and has come to the conclusion that in order to get the velocity of light along a stream of flowing water we have to add to the velocity of light only half the velocity of water. The following considerations suggest themselves to me with respect to this result. Maxwell's theory is founded on certain observed effects, which all depend on the relative motion of matter. A result such as the one referred to implies actions depending on absolute motion, and appears therefore to point to something which has been introduced into the equations for which there is no experimental evidence. The only assumption clearly put down by Maxwell is that electromagnetic actions are transmitted through the medium, and it is possible that that assumption necessarily carries Professor J. J. Thomson's result with it. If a careful examination of the subject should show that this is the case, we are brought face to face with a serious difficulty. It is said, with justice, to be one of the great advantages of Maxwell's theory that it does away with action at a distance; but what do we gain if we replace action at a distance by something infinitely more difficult to conceive, namely, internal stresses of a medium depending on the velocity of the medium

[1] Fizeau's result must either be due to the motion of matter through the medium or to the fact that moving matter carries the ether with it. If it is due to the former cause, and matter does *not* carry the ether with it, may we not consider that matter moving through the ether, that is a relative motion of matter and ether, must produce effects equal and opposite to those of ether moving through matter? In that case the reasoning in the text would, *mutatis mutandis*, hold good.

[2] *Phil. Mag.*, vol. ix. 1880, p. 284.

through space? I can only see one loophole through which to escape, namely, that Maxwell's medium is not homogeneous, but consists of two parts, and that if we speak of the medium as moving we mean the motion of one of these parts relative to the other.

While we may hope to obtain important results from an investigation of the relation between what we call electricity and the medium, we must not lose sight of another avenue, namely, the relation between electricity and chemical effects. The passage of electricity through gases presents us with a complicated problem to which a number of physicists have given their attention of late years. There seems no reasonable doubt that electricity in a gas is conveyed by the diffusion of particles conveying high charges, probably identical with those carried by the electrolytic ions. The fact that this convection is a process of diffusion with comparatively small velocity is shown by the experimental result that the path of the discharge is affected by any bodily motion of the gas which conveys the current. Even the convection currents due to the heat produced by the discharge itself are sufficient to deflect the luminous column which marks the passage of the current.

The most puzzling fact, however, connected with the discharge of electricity through gases consists in the absence of symmetry at the positive and negative poles. There must be some difference between a positively and a negatively charged atom which seems of fundamental importance in the relation between matter and what we call electricity. A discussion of the various phenomena attending the discharge of electricity through gases seems to me to point to a conclusion which may possibly prove a step in the right direction.

A surface of separation between bodies having different conductivities becomes electrified by the passage of a current, while at the surface between two chemically distinct bodies we have, according to Helmholtz, a sheet covered at the two sides with opposite electricities. These surface electrifications are not merely imaginary layers invented to satisfy mathematical surface conditions. They can be proved to be realities. Thus, when one electrolyte floats on another, the specific resistances being different, we often observe secondary chemical effects due to the action of the ions which carry the surface electrification.

If the passage of electricity from the solid to the gas involves some work done, we must expect a double sheet of electricity at the boundary, the gas in contact with the kathode becoming positively, and that in contact with the anode negatively, electrified. *A priori* we can form no idea how a layer of gas, the atoms of which carry charges, will behave. The ordinary proof that all electrification must be confined to the surface implies that all forces act according to the law of the inverse square; but where we have also to consider molecular forces, I see no reason why the electrification at a surface may not stretch across a layer having a thickness comparable with the mean free path of the molecule. It is here that there seems to be the fundamental difference between positive and negative electricity. A negative electrification of the gas, like that of a solid or a liquid, seems always confined to the surface, and no one has ever observed a volume electrification of negative electricity. The case is different for the positively electrified part of the gas. Wherever from other considerations we should expect a positively electrified surface sheet, we always get a layer of finite thickness. The result implies a different law of impact between positively and negatively electrified ions, but I see no inherent improbability in this. That the kathode let into a gas is surrounded by a positively electrified layer of finite thickness extending outwards must be considered as an established fact, and several of the characteristic features of the discharge are explained by it. The large fall of potential at the kathode can also be explained on the view which I have put forward, for in order to keep up the discharge there must be a sufficient normal force at the surface, and if this force is not confined to the surface, but necessarily stretches across a finite layer, the fall of potential must be multiplied a great number of times. Similarly Goldstein has shown that some of the phenomena of the kathode are observed at every place at which the positive current flows from a wide to a narrow part of a column of gas. At such places we should expect a positive surface electrification, and here, again, the whole appearance tends to show that we are dealing

with a positive volume electrification. No corresponding phenomena are observed when the current passes from the narrow to the wide part.

The fact that in all cases experimented upon positive volume electrifications are observed but never similar negative electrifications is surely of significance.

Some of the results recently brought to light by investigations on the discharge of electricity have interesting cosmical applications. Thus it is found that such a discharge through any part of a vessel containing a gas converts the whole gas into a conductor.[1] The dissociation which we imagine to take place in a liquid before electrolytic conduction takes place must be artificially produced in a gas by the discharge itself. We may imitate in gases which have thus been rendered conductive many of the phenomena hitherto restricted to liquids: thus I hope to bring to the notice of this meeting cases of primary and secondary cells in which the electrolyte is a gas. There are other ways in which a gas can be put into that sensitive state in which we may treat it as a conductor, and we have every reason to suppose that the upper regions of our atmosphere are in this state. The principal part of the daily variation of the magnetic needle is due to causes lying outside the surface of the earth, and is in all probability only an electromagnetic effect due to that bodily motion in our atmosphere which shows itself in the diurnal changes of the barometer. A favourite idea of the late Professor Balfour Stewart will probably be thus confirmed. The difference in the diurnal range between times of maximum and times of minimum sun-spots is accounted for by the fact that the atmosphere is a better conductor at times of maximum sun-spots.

The mention of sun-spots raises a point not altogether new to this section. Careful observations of celestial phenomena may suggest to us the solution of many mysteries which are now puzzling us. Consider, for instance, how long it would have taken to prove the universal property of gravitational attraction if the record of planetary motion had not come to the philosopher's help. And surely the most casual observation of cosmical effects teaches us how much we have yet to learn.

The statement of a problem occasionally helps to clear it up, and I may be allowed, therefore, to put before you some questions, the solution of which seems not beyond the reach of our powers.

1. Is every large rotating mass a magnet? If it is, the sun must be a powerful magnet. The comets' tails, which eclipse observations show stretching out from our sun in all directions, probably consist of electric discharges. The effect of a magnet on the discharge is known, and careful investigations of the streamers of the solar corona ought to give an answer to the question which I have put.[2]

2. Is there sufficient matter in interplanetary space to make it a conductor of electricity? I believe the evidence to be in favour of that view. But the conductivity can only be small, for otherwise the earth would gradually set itself to revolve about its magnetic pole. Suppose the electric resistance of interplanetary space to be so great that no appreciable change in the earth's axis of rotation could have taken place within historical times; is it not possible that the currents induced in planetary space by the earth's revolution may, by their electromagnetic action, cause the secular variation of terrestrial magnetism? There seems to me to be here a definite question capable of a definite answer, and as far as I can judge without a strict mathematical investigation the answer is in the affirmative.

3. What is a sun-spot? It is, I believe, generally assumed that it is analogous to one of our cyclones. The general appearance of a sun-spot does not show any marked cyclonic motion, though what we see is really determined by the distribution of temperature, and not by the lines of flow. But a number of cyclones clustering together like the sun-spots in a group should move round each other in a definite

[1] An experiment by Hittorf (*Wied. Ann.*, vii. p. 614) suggested the probability of this fact, which was proved independently by Arrhenius and myself.

[2] The efforts of Mr. Bigelow have a bearing on this point, also some remarks which I have made in a lecture before the Royal Institution (*Proc. Roy. Inst.*, 1891), but nothing decisive can be asserted at present.

way, and it seems to me that the close study of the relative positions of a group of spots should give decisive evidence for or against the cyclone theory.

4. If the spot is not due to cyclonic motion, is it not possible that electric discharges setting out from the sun, and accelerating artificially evaporation at the sun's surface, might cool those parts from which the discharge starts, and thus produce a sun-spot? The effects of electric discharges on matters of solar physics have already been discussed by Dr. Huggins.

5. May not the periodicity of sun-spots, and the connection between two such dissimilar phenomena as spots on the sun and magnetic disturbances on the earth, be due to a periodically recurring increase in the electric conductivity of the parts of space surrounding the sun? Such an increase of conductivity might be produced by meteoric matter circulating round the sun.

6. What causes the anomalous law of rotation of the solar photosphere? It has long been known that groups of spots at the solar equator perform their revolution in a shorter time than those in a higher latitude; but spots are disturbances which may have their own proper motions. Dunér[1] has shown, however, from the displacement of the Fraunhofer lines, that the whole of the layer which produces these lines follows the same anomalous law, the angular velocity at a latitude of 75° being 30 per cent. less than near the equator.[2] As all causes acting within the sun might cause the angular velocity of the sun to be smaller at the equator than at other latitudes, but could not make it greater, the only explanation open to us is an outside effect either by an influx of meteoric matter, as suggested by Lord Kelvin, or in some other way. If we are to trust Dr. Welsing's result that faculæ which have their seat below the photosphere revolve in all latitudes with the same velocity, which is that of the spot velocity in the equatorial region, we should have to find a cause for a retardation in higher latitudes rather than for an acceleration at the equator. The exceptional behaviour of the solar surface seems to me to deserve very careful attention from solar physicists. Its explanation will probably carry with it that of many other phenomena.

In conclusion, I should like to return for an instant to the question whether it is possible by any means to render the progress of science more smooth and swift. If there is any truth in the idea that two types of mind are necessary, the one corresponding to the boiler and the other to the cooler of a steam engine, it must also be true that some place must be found where the two may bring their influence to bear on each other. I venture to think that no better ground can be chosen than that supplied by our meetings. We hear it said that the British Association has fulfilled its object; we are told that it was originally founded to create a general interest in scientific problems in the towns in which it meets; and now that popular lectures and popular literature are supposed to perform that work more satisfactorily, we are politely asked to commit the happy despatch. There is no need to go back to the original intention of those who have founded this institution, which has at any rate adapted itself sufficiently well to the altered circumstances to maintain a beneficial influence in scientific research.

The free discussion which takes place in our sections, the interchange of ideas between men who during the rest of the year have occupied their minds, perhaps too much, with some special problem, the personal intercourse between those who are beginning their work with sanguine expectations, and those who have lost the first freshness of their enthusiasm, should surely one and all ensure a long prosperity to our meetings. If we cannot claim any longer to sow the seeds of scientific interest in the towns we visit, because the interest is established, we can at any rate assure those who so kindly offer us hospitality that they are helping powerfully in the promotion of the great object which we all have at heart.

[1] *Oefvers. af Kongl. Vetensk. Ak. Förhandl.*, xlvii. 1890.

[2] Although the importance of M. Dunér's results would make an independent investigation desirable, the measurements of Mr. Crew, who by a much inferior method arrived at other results, cannot have much weight as compared with those of Dunér.

The following Reports and Papers were read:—

1. *Report of the Committee on the Meteorological Observations on Ben Nevis.*—See Reports, p. 68.

2. *Second Report of the Committee on Meteorological Photography.* See Reports, p. 77.

3. *Eighth Report of the Committee on Solar Radiation.* See Reports, p. 158.

4. *Interim Report of the Committee on Meteoric Dust.*

5. *Twelfth Report of the Committee on the Seismological Phenomena of Japan.*—See Reports, p. 93.

6. *Nineteenth Report of the Committee on Underground Temperature.* See Reports, p. 129.

7. *Preliminary Account of Oceanic Circulation, based on the 'Challenger' Observations. By* Dr. A. Buchan, *F.R.S.E.*

8. *On the Advantage of making Astronomical Time agree with Civil Time. By* Dr. Sandford Fleming, *C.M.G.*

9. *York Weather from* 1841 *to* 1890. *By* J. Edmund Clark.

Fifty years of observations with reliable instruments would appear sufficient to give the annual mean pressure accurately within one-hundredth of an inch; temperature within $\frac{1}{5}$° F.; rainfall within 2 per cent. of the total fall. Extremes require a much longer period, and monthly means are of course intermediate.

The means of the three chief values for York are:—Pressure, 29·904 inches; temperature (9 A.M. and 9 P.M.), 47°·3 F.; rainfall, 25·005 inches. The mean relative humidity has been reduced for only $12\frac{2}{3}$ years, for which the value is 85·0.

FRIDAY, AUGUST 5.

The following Papers were read:—

1. *On Leaky Magnetic Circuits. By* Dr. H. E. J. G. du Bois.

In order to obtain some generally reliable result on this question the particular case of a split-ring, magnetised uniformly and peripherically, was investigated theoretically as well as experimentally. The values of the demagnetising factor were found to approximate more and more towards the theoretical values as the magnetising field is increased—as, indeed, they should by a general saturation theorem, first given by Kirchhoff. For a lower range of magnetisation, up to about half the saturation value, the factors are constant, and smaller than the theoretical values. It may be shown that the leakage coefficients, as defined by Hopkinson, are proportional to the reciprocals of the above factors; it thence follows that leakage decreases for high magnetisation, contrary to what has hitherto generally

been supposed to occur. This unexpected behaviour may be explained by the proper physical theory, but cannot be accounted for by the ohmic law for magnetic circuits.

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2. *On M. E. Branly's Experiments on Electrical Resistance.*

By Dawson Turner, *M.D.*

The author had the pleasure, when in Paris, of seeing some of M. E. Branly's experiments on the influence of currents of high potential upon electrical resistance (an account of which has been published by M. Branly in the 'Comptes Rendus,' November 24, 1890, and January 12, 1891; also in the 'Bulletin de la Soc. Int. des Electriciens,' No. 78, May 1891). The author has repeated some of these. It is well known that metallic powders present a very great electrical resistance. This can be lowered to an extraordinary degree by the passage of a spark in their neighbourhood. The author, following M. Branly, has tried, amongst other substances, powdered aluminium, copper, annealed selenium, iron filings, small shot, mixtures of aluminium and resin fused into a solid stick, &c. The best results were obtained with the first two. A short glass tube is filled with powdered aluminium, and placed, by means of copper wires passing through corks, in circuit with one or two cells and a galvanometer. The resistance of the aluminium is very great, and the needle of the galvanometer will remain at zero. If, however, a spark from an induction coil be passed anywhere in the vicinity, the resistance will become at once very much diminished and the galvanometer needle will be deflected. Thus, though there was at first no appreciable current, there may now be one of 250 m.a. The powder will, if undisturbed, remain a conductor for some little time; but if the table be shaken, or the glass tube be moved, the initial resistance at once returns and the needle passes back to zero. After the resistance has been once lowered in this way the powder gets into a very sensitive condition; a spark at a great distance lowers the resistance, and the slightest jar restores it. The author was not successful with ordinary iron filings, perhaps because they were not sufficiently finely divided. Mere shaking does not restore the resistance of the solid stick of aluminium and resin, but the application of a little warmth is sufficient.

The experiments would appear to suggest that the molecules of the powders become arranged in such an order as to conduct electricity when an electrical discharge occurs in their neighbourhood, and that the slightest mechanical jarring suffices to destroy this arrangement. It does not appear to matter which way the induction current is passed.

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3. *On Electrical Discharges.*

By Professor Eilh. Wiedemann *and* Dr. H. Ebert.

The object of the experiments to be described was to study the phenomena of electrical discharges in rarefied gases under the influence of electrical oscillations of a well-defined period, so as to get a deeper insight into their nature. For producing regular electric motions the authors adopted the method of Lecher, but they substituted for the induction coil, with its complicated form of discharge, a Töpler machine of twenty rotating plates, purchased out of a grant given by the Elisabeth Thompson fund. The Lecher wires were between 6 and 14 metres long; by means of bridges resonating circuits of definite period were formed; the ends of the wires were connected with the plates of a Kohlrausch condenser—the 'End Condenser.'

Like other experimenters, the authors found in the beginning a great difficulty, sometimes impossibility, in getting a luminosity of the tube laid between or at the sides of the end condenser, if it was of small diameter. Larger tubes were much more easily excited. But it was found that tubes, not too small, with inside coatings of platinum, always gave luminosity, and that if they were brought near other insensitive tubes these also began to glow, and even did so after the exciting tube had been removed.

The phenomena are described which occurred in different tubes and in different positions, especially curious dark spaces in the neighbourhood of the condenser's plates in the vacuum tubes, through which the oscillations passed unabsorbed. Some cases were discussed in which the discharges ceased in a singular manner by improving the vacuum.

The paper is to be published in full in Wiedemann's 'Annalen.' An account of some of the experiments, with an explanation of them, has been published already in the 'Verhandl. der Societas Physico-Medica' of Erlangen, 1892.

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4. *On Primary and Secondary Batteries in which the Electrolyte is a Gas.* *By* Arthur Schuster, *F.R.S.*

If a current of electricity passes through a vessel which is partially exhausted, the whole gas contained in the vessel becomes a conductor in the ordinary sense, and a single cell will send a measurable current through it. This phenomenon, which may conveniently be called 'secondary conduction,' has been investigated by the author and Professor Arrhenius. A more detailed study during the past year has brought some interesting phenomena to light. If the secondary electrodes are platinum and the gas is a hydrocarbon, phenomena of polarisation are observed exactly similar to those found when water is decomposed. The electromotive force of polarisation in that case amounts to about three or four volts. No polarisation or traces only are found with hydrogen, oxygen, nitrogen, cyanogen, aqueous vapour, ammonia, and other gases experimented upon, but phosphoretted hydrogen shows the phenomenon.

When the electrodes are made of copper or iron no polarisation is observed in hydrocarbons. On the other hand, when aluminum or magnesium is used it rises to very high values. Magnesium electrodes, in which the secondary current from thirty Clark cells was allowed to pass for some time, showed a polarisation of 35 volts.

The polarisation effects are studied just as in the case of liquids by interrupting the polarising current and connecting the secondary electrodes with a galvanometer or electrometer.

When a hydrocarbon is used both electrodes become covered with a thin film, which shows the colours of thin layers of metallic oxides or sulphides. The fact that the electromotive force depends so much on the nature of the metal tends to show that a metallic carbon compound is formed by the action of the primary current, and that the effects are analogous to those of the secondary battery.

The author has also studied the currents observed when electrodes of different metals are inserted into a gas rendered sensitive by the electric discharge. Arrhenius had already shown that zinc and platinum in air give a permanent difference of potential under these circumstances. The author finds that, whatever the gas which has been converted into a conductor by a primary discharge, permanent currents may be obtained from magnesium and platinum electrodes, the magnesium always being electro-negative. The electromotive force is, however, different in different gases, and higher, for instance, in oxygen than in hydrogen.

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5. *On the Stability of Periodic Motion.* *By* Lord Kelvin, *F.R.S.*

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6. *The Efficiency of Transformers.*
By Professor W. E. Ayrton, *F.R.S.*, *and* W. E. Sumpner.

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7. *Note on the Registration of Transformers.*
By Professor W. E. Ayrton, *F.R.S.*, *and* E. W. Smith.

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8. *Specific Conductivity of Thin Films.*

By Professor A. W. Reinold, *F.R.S.*, *and* Professor A. W. Rücker, *F.R.S.*

The authors have found that the specific conductivity of liquids formed of soap and water, and containing a considerable proportion of glycerine and a small percentage of a metallic salt, is the same whether the liquid is in large mass or is drawn out into a film not thicker than one two hundred thousandth of an inch. This is not the case if the liquid be formed of soap and water only. In that case the specific electrical conductivity increases as the film becomes thinner, until for the thinnest films which have been observed it is about seven times greater than in a large mass of the same liquid. Newton observed in very thin films (which appear black) two shades corresponding to two different thicknesses. The authors find that this phenomenon is only observed when the liquid consists of soap and water only, and they have some reason to believe that the ratio of the thicknesses corresponding to the two tints is about two to one.

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9. *Some Experiments with a Ruhmkorff Coil.*

By Magnus Maclean, *M.A.*, *F.R.S.E.*, *and* Alex. Galt, *B.Sc.*, *F.R.S.E.*

The quantity of electricity induced in a secondary circuit by a *make* in a primary circuit is equal to the quantity of electricity induced in the same secondary by a *break* in the primary. This fact was first experimentally proved by Faraday, and subsequent experiments and theory corroborate the statement. If, however, there is a non-metallic gap in the circuit, whether of air at ordinary pressure or at much reduced pressure, as in vacuum tubes, the *break* impulse causes a flow in one direction, and the *make* causes either no flow, or a much less flow in the opposite direction; because the short intense impulse of the former breaks down the resistance, while the comparatively long and less intense impulse of the make either does not break down the resistance at all, or only does so to a much less degree, so that the effective resistance is much greater in one direction than in the other. To obtain the average difference of quantity of electricity set in motion in one direction above that in the other a copper electrolytic cell was put in circuit with a vacuum tube and the secondary coil of a small Ruhmkorff coil. The solution in the cell was sulphate of copper of density 1·17 with one-half per cent. of commercial sulphuric acid added. The electrodes were No. 36 B.W.G. copper wire [0·0102 centimetre diameter]; and they were immersed in the solution as little as possible so as to get the best current density for the deposit. The mean of seven experiments lasting from two to four hours gives the average electrolytic current, calculated from the gain of the cathode electrode, as one-sixth of a milliampère. The gain of the cathode electrode was, in six of the seven experiments, greater than the loss of the anode electrode. An electrolytic cell was also put into the primary, and the mean ratio, in three experiments, between the gain of the cathode in the primary and the gain of the cathode in the secondary was 6,000. The mean current in the secondary was still about one-sixth of a milliampère.

Two experiments were also tried without a vacuum tube in the secondary circuit—simply the electrolytic cell. Both electrodes showed loss. Again, a long thermometer tube full of sulphate of copper solution was substituted for the vacuum tube. The resistance of this tube would be comparable to that of the vacuum tube. [A Thomson multicellular electrometer which was put at the terminals of the vacuum tube showed 165 volts. This would give the effective resistance of the vacuum tube to disruptive discharges as $165 \div \frac{1}{6000} \doteqdot 1$ megohm.] The few experiments made with this thermometer tube in the circuit are inconclusive, as sometimes both electrodes showed loss, and in an experiment lasting five or six hours neither electrode showed either gain or loss. These last experiments are to be continued, with slight modifications. It is also intended to attach a tube to an exhaust pump, and try these electrolytic experiments at different pressures from atmospheric pressure down to very low pressures.

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10. *A Contribution to the Theory of the perfect Influence Machine.* By J. Gray, *B.Sc.*

The theory of the perfect influence machine has been shown by Clerk Maxwell to be analogous to Carnot's theory of the perfect heat-engine. Maxwell points out there is a loss of energy in the ordinary influence machine through sparking at the contacts, which would render the machine inefficient even though losses from leakage and the like were completely done away with. Maxwell has described a machine in which sparking and the loss due to it are eliminated. This is done by causing the carrier of electricity always to make contact with charging and discharging conductors when the former is at the same potential as the latter. In the case of the discharging conductors this is done by prolonging the contact springs to meet the carrier. In case of the charging conductors this is not sufficient; it is necessary to surround the end of their contact springs by two additional conductors charged to an equal and opposite potential, and of such a capacity as will just reduce to zero the potential of the small quantity of electricity left from the previous discharge. These additional conductors were called by Maxwell regenerators, as being analogous to regenerators in the heat-engine.

The object of the author is to investigate the efficiency of an influence machine constructed according to Maxwell's design, and other designs less perfect. This is done by drawing a Q V (quantity-potential) energy diagram for one revolution of the carrier. The results obtained are as follows:—

	Theoretical efficiency
Maxwell's machine	1
„ „ without regenerators . . .	$\dfrac{1}{1+\frac{\frac{1}{2}av}{Q}}$
„ „ without long contacts on receivers	$\dfrac{2}{3}$
„ „ without regenerators and without long contacts on chargers . .	$\dfrac{1}{1\frac{1}{2}+\frac{aV}{Q}}$
Ordinary machine with all contacts points . .	$\dfrac{1}{2+\frac{aV}{Q}}$

where Q = quantity received or discharged by a carrier in each revolution.
V = the potential (numerical value) of the positive or negative receiver.
v = the potential of the residual charge to be reduced to zero by the regenerator.
a = the part of the carrier's capacity due to its not being completely surrounded by the discharging conductor.

The conclusion is that the regenerators are of much less importance than the long contacts in adding to the efficiency of an influence machine.

SATURDAY, AUGUST 6.

The following Papers and Reports were read:—

Department I.—Physics.

1. *Sources of Heat generated in the Galvanic Battery.* By Magnus Maclean, *M.A., F.R.S.E.*

These experiments were suggested by a paper read by Lord Kelvin to the British Association in Belfast in 1852, and reprinted in 'Mathematical and Physical

Papers,' art. lv. In that article it is stated 'that a feeble continued current, passing out of an electrolytic cell by a zinc electrode, must generate exactly as much more heat at the zinc surface than the same amount of current would develop in passing out of an electrolytic cell by a platinum electrode, as a zinc platinum pair working against great external resistance would develop in the resistance wire by the same amount of current.'

In the first set of experiments two equal and similar glass vessels were used with about 500 c.c. of dilute sulphuric acid in each. The pairs of elements were Zn, Zn; Zn, Pt. The rise of temperature, due to currents of from 4 to 14 milliampères, obtained from the Smee cell, was observed at intervals of a few minutes for about four hours. There are many sources of errors in this mode of experimenting, but generally the rise of temperature of the Zn, Zn cell was greater than that in the Smee cell. In some of the experiments the Smee cell showed a higher rise of temperature; but this latter result is no doubt due to local causes, such as polarisation, &c.

In the second set of experiments a current of 39 milliampères was obtained from the Smee cell, and in every case the rise of temperature of the Zn, Zn cell was greater than the rise of temperature of the Smee cell, and the average rise corroborates the statement of Lord Kelvin quoted above.

In the third set of experiments the two elements in each cell were separated by a piece of blotting-paper, and four thermometers used to indicate the rise of temperature at each electrode. It was found that the rise of temperature at the zinc anode plate was greater than at the zinc cathode.

In another series of experiments with four cells containing dilute sulphuric acid in which the pairs of elements were Zn Zn, Pt Pt, Pt Zn, Zn Pt, currents from an external source of $\frac{1}{2}$, 1, and 2 ampères, were allowed to flow for about an hour, and the rise of temperature in each cell recorded. Tables of results are given showing that the rise of temperature in the cell in which the current flowed from platinum to zinc is in every case higher than the rise of temperature in the cell in which the current flows from zinc to platinum. Taking the average of a number of experiments fairly agreeing among themselves, it is found that the mean rise of temperature in the four cells above the rise of temperature of the laboratory is—

← *Direction of Current.*

—	Z. Z.	P. P.	P. Z.	Z. P.
1 hour ½ ampère . .	0·45	0·6	0·53	1·07 mean of 3 experiments
40 mins. 1 „ . .	0·45	0·75	0·6	1·37 „ 3 „
1 hour 2 ampères . .	2·8	3·98	2·53	4·98 „ 4 „

Mr. George E. Allan, Thomson Scholar in the Physical Laboratory of the University of Glasgow, has carried out the greater number of the later experiments.

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2. *On the Electric Conductivity of Bismuth and Copper in Magnetic Fields.* *By* Dr. W. Peddie, *F.R.S.E.*

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3. *The Application of Interference Methods to Spectroscopic Measurement.* *By* Professor A. Michelson.—See Reports, p. 170.

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4. *Photographs of Electrical Discharges.*
By A. A. Campbell Swinton.

The photographs exhibited were all obtained without the employment of any lens, and were produced by merely causing the electric discharges to take place

across the sensitive surface of ordinary gelatino-bromide dry plates. Discharges (1) from a Wimshurst influence machine, (2) from an induction coil, and (3) from a Tesla high-frequency coil were among those shown. The entirely distinctive character of figure produced by positive and by negative discharges respectively was very noticeable in all the photographs, the former being of an irregular description somewhat resembling some forms of seaweed, the latter forming straight lines or sweeping curves with feather-like extremities. In fact, while the negative figures point to something of the nature of momentum in the discharge, and give the idea of a stream issuing from the electrode and splashing over the surface of the glass, the positive figures, on the other hand, seem more nearly allied to streams flowing from the glass to the electrode and sucking from all portions of the plate. A remarkable similarity was noticeable between some of the figures and organic forms, such as some descriptions of seaweed in the case of the positive, and feathers or palm-leaves in the case of the negative. The figures in fact present another curious instance of the remarkable manner in which under favourable conditions inorganic matter will assume the structural forms generally associated with organic life. The figures appear to be accurate representations of the actual discharges produced by the ordinary photographic action of the luminosity of the latter, and the gelatine film seems to have no appreciable effect in altering the form of the discharges, which are the same as those obtained on plain glass.

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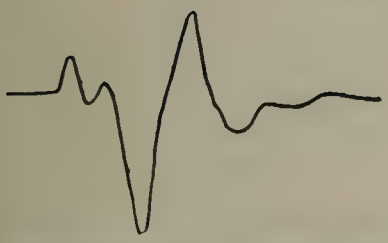
5. *Slow Oscillations produced on discharging Electric Condensers of great Capacity.* By James H. Gray, *M.A., B.Sc.*

About the end of last winter Lord Kelvin asked the author to try to obtain oscillations on the discharge of a condenser through inductive resistances which would be slow enough to be observed by means of a mirror-galvanometer. For that purpose use was made of a set of eleven large condensers (total capacity about 140 microfarads) which are in the Physical Laboratory of Glasgow University. The capacity being so large, the author hoped to be able to detect oscillations of periods comparable with one second without making the ratio of damping inconveniently great. Applying the now well-known differential equation—

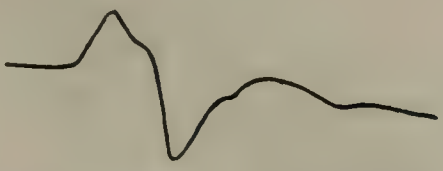
$$\frac{d^2q}{dt^2} + \frac{R}{L}\frac{dq}{dt} + \frac{1}{CL}q = 0,$$

where the symbols have their usual meaning, we see that, in order to get slow oscillations, the resistance of the discharging circuit must be as small as possible compared with its self-induction, and the capacity of the condenser as great as can conveniently be made. The author endeavoured to obtain these conditions, and succeeded in so far that, though the ratio of damping was considerably removed from unity, it was found possible to record at least three semi-oscillations on each discharge. When the frequency of the oscillations is very great (for example, about 10,000 per second, as in the experiments of Feddersen, Paalzow, Blaserna, and others), it is very easy to make the ratio of damping practically unity; but when the frequency is only two or three per second, this is very difficult, and the only way to obtain results is to make the capacity and self-induction as large as possible. In order to obtain a high self-induction, a large electro-magnet which formerly belonged to a dynamo was used as part of the discharging circuit. The diameter of the iron core was 13 centimetres, the length of each coil of wire being 28½ centimetres. There were on each coil about 44 lbs. of No. 20 B.W.G. covered copper wire, 7,300 turns, and 28 layers, the outside diameter of the coils being 18½ centimetres. The resistance of each was about 95 (B.A.) ohms. It was found difficult to adjust the mirror galvanometer to detect the oscillations, but they were observed by means of a telephone of low resistance, and distinctly seen when, at the suggestion of Mr. C. T. Littlewood, B.Sc., a thin strip of sheet iron was placed with one end about 5 millimetres from one pole of the magnet, so as to vibrate freely. At each semi-oscillation the sheet iron was attracted. To prove that this was not due merely to the free period

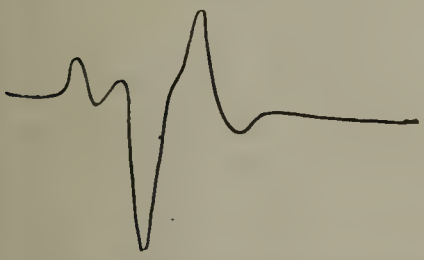
Electric Oscillations.



1. One magnet-coil only, in discharging circuit.

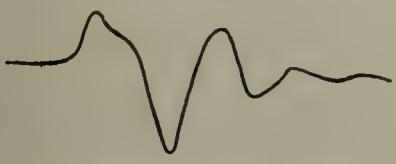


6. Both magnet-coils in discharging circuit.

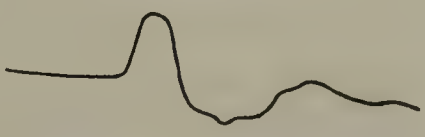


2. One magnet-coil and 10 ohms (wound anti-inductively).

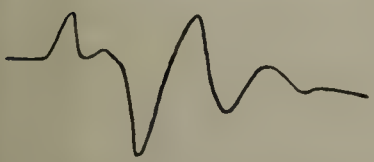
7. Both magnet-coils and 10 ohms (wound anti-inductively).



3. One magnet-coil and 100 ohms (wound anti-inductively).



8. Both magnet-coils and 100 ohms (wound anti-inductively).

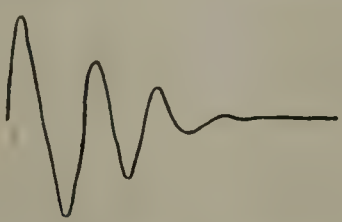


4. One magnet-coil and 145 ohms (wound inductively).

9. Both magnet-coils and 145 ohms (wound inductively).

5. One magnet-coil and 293 ohms (wound anti-inductively).

10. Both magnet-coils and 1000 ohms (induction small).



11. Free vibration of pendulum.

of the strip, the latter was clamped at different distances from the end, and this was found to make no difference in the time which elapsed between each attraction as long as the discharging circuit was not altered. When, however, the resistance was increased without correspondingly increasing the self-induction, the time between successive attractions was diminished. In order to obtain a permanent record of these attractions, the end of the strip was placed in contact with sooted paper, which revolved uniformly on a small roller rotating about a vertical axis. The results obtained showed usually three attractions, and showed very clearly the effect of including more resistance and more self-induction, with one or both coils of electro-magnet. This method, however, did not demonstrate that there was actually a reversal in the current at each semi-oscillation, and therefore it was abandoned. The recording apparatus of a siphon-recorder was then used, but it was found to be too delicate for the rough apparatus employed. Ultimately a long thin permanent magnet was fixed so as to vibrate, with one end over a pole of the electro-magnet. By this both an attraction and repulsion could be registered. The tracings shown give the compound harmonic motions made up of the free vibrations of the permanent magnet and of the oscillations. The different tracings show the effect of having both coils in the circuit and of including extra coils, some being wound non-inductively and some inductively. The free vibration of the magnet is also shown. The charging potential was about 90 volts. This method and the curves are, of course, not intended to be used for quantitative purposes, but are given simply as a verification of the theory of the oscillatory discharge, and as of interest on account of the oscillations being so slow.

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6. *Inducto-Script.* *By* Rev. Frederick J. Smith, *M.A.*

The well-known breath figures of Möser, Riess, and Karsten suggested to the author the idea of producing similar figures on photographic plates; in 1878 an experiment to determine the action of a discharge from a coin on to a photo-plate was tried. The image was produced on development, but very imperfectly. During the last two years an inductorium or transformer has been under constant trial. It occurred to the author that probably its high potential might be used to produce figures similar to those of Karsten: plates of glass were cleaned with care, and operated on in the way suggested by Karsten, but no results were to be got out of it; probably the potential difference was not great enough.

A photo-plate was used in the place of the glass, and on development the exact pattern of the medal used was produced; this showed that a potential difference, greatly under that of a jar discharge, or that of an electrical machine, would upset the chemical equilibrium of the photo-plate. Several factors appeared to be contributing to the result—the potential difference, the gas in which the experiment was performed, the pressure under which the experiment was done, the temperature, and the history of the plate previous to the experiment.

It is to be noticed in reading the work on breath figures by Grove and Karsten that Grove tried to set the image by coating an electrised plate with collodion and nitrate of silver, and then developed out the word Volta (Grove, 'Correlation of Physical Forces,' 1870, p. 404, § 4). He did not let *the electrical discharge to act on the silver salt.* Again, Karsten did not succeed in producing a fixed picture on a daguerreotype plate. He writes: 'If an iodised plate is taken, and a picture produced thereon, the vapour of mercury will not bring it out, although the image is really on the plate, as may be shown by breathing upon it.' Möser appears to have got out pictures by means of water vapour, but they were not permanent effects.

Summary of results:—

I. The different gases used were oxygen, carbonic acid gas, air, coal-gas. Far the best results were obtained in oxygen. Experiments with other gases are now being made.

II. The effect of pressure. No picture could be obtained in a good vacuum,

only the circular shape of the coin; as the pressure increased towards the normal the pictures became more perfect.

III. The output of the transformer was regulated by resistances put into the primary circuit, also by the rate at which the reversing commutator was driven; the reversing commutator is similar to those used in the early Siemens machine, and driven from a belt in the laboratory.

IV. The temperature varied between 5° C. and 100° C. Perhaps the effects may have been produced more quickly at the higher temperature, but no very significant change was apparent.

V. Similar experiments are about to be performed in many other gases, and under considerable pressure, up to 10 atmospheres.

VI. In addition to pictures on photo-plates, good impressions have been obtained on bromide paper and other papers direct. Pictures can easily be got from woodcuts after they have been well covered with plumbago and other conducting substances.

VII. Impressions can be produced upon photo-plates which have been exposed to full sunlight previous to an inducto-script experiment. The development of the electrical picture appears to be independent of the condition of the plate due to light. Thus an ordinary photograph and an inductograph may be produced on the same plate.

VIII. In some cases the plate, on which a good image was formed, was very carefully insulated, so that it was as far as possible only subject to a quickly changing potential difference.

IX. In one experiment a metal pointer was attached to the coil of a siphon recorder, and nearly touched a ribbon of bromide paper; on development the trace was evident. The experiment is now being repeated, under somewhat altered conditions, to determine the speed at which such signals can be made perfectly.

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7. *On a Periodic Effect which the Size of Bubbles has on the Velocity of their Ascent in Vertical Tubes containing Liquid.* *By* FRED. T. TROUTON, *M.A., D.Sc.*

An account was given of some determinations made of the velocity with which bubbles of air of different sizes ascend vertical tubes containing water. The chief peculiarity brought out by these experiments is that the velocity of ascent is a periodic function of the size of the bubbles. The form of the curve, obtained by plotting the size, *i.e.*, the volume of the different bubbles used as abscissæ, and the corresponding values of the velocity of ascent as ordinates, was exhibited. This showed that at first, as would be expected, increase in size diminished the velocity, but that on reaching a certain size the velocity begins to increase in value, then comes to a maximum (in value about twice that of the minimum velocity), after which it again diminishes, and so on two or more times, depending on the diameter of the tube employed. The oscillations in the curve die out in much the same fashion as that for a pendulum swinging in a viscous medium. The form taken by the bubbles was also described, being almost spherical at the first minimum; beyond this the bubble is pointed at top, and is so until reaching the second minimum, when it is again rounded at top, and has a waist-like appearance, having thus a somewhat dumbbell shape, and so on, presenting in this way similarities to the breaking up of a liquid column through surface tension.

Experiments were described where liquids which do not mix with water were employed instead of air—such affording more simple conditions. Also some experiments similar to those with water, but made with other liquids.

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8. *Experiments on Flame Spectra.*
By Professor ARTHUR SMITHELLS, *B.Sc.*

The author exhibited his apparatus for separating the two cones of combustion which constitute a Bunsen flame, and showed how it afforded a means of ascer-

taining which part of the flame took part in the production of the spectra observed when metallic salts are introduced into non-luminous flames. The main conclusion derived was, that spectral effects are dependent, in the cases investigated, on radiations produced during chemical change, and not to molecular vibrations induced by external heating. An experiment was shown in which a spray of a solution of a copper salt was introduced into the two separated cones of a non-luminous flame. Decomposition of the salt took place in the inner and hotter cone without the production of a spectrum, whilst the products of decomposition on reaching the outer flame tinged it a brilliant green. This spectrum was thus shown to depend on chemical action, and not merely on external heating, the action in this case being evidently the formation of copper oxide. The formation of copper chloride, which could be effected by introducing a thread of asbestos, moistened with hydrochloric acid, into the outer cone, gave a beautiful blue colour. Gold chloride similarly employed was decomposed also in the lower cone without producing a spectrum. The separated gold passed into the upper flame, which was faintly tinged; but if a little hydrochloric acid were introduced, a beautiful green colour (due to gold chloride) was observed. The action between gold and hydrochloric acid at a temperature above that at which gold chloride dissociates, and below that at which hydrochloric acid dissociates, seemed highly anomalous. The author did not wish at present to draw any final conclusions, but considered that his experiments disclosed the necessity for a thorough study of the chemical reactions taking place when metallic salts are producing spectra in non-luminous flames.

Department II.—Mathematics.

1. *Models of Mathematical Surfaces.* *By* Professor A. Crum Brown, *F.R.S., F.R.S.E.*

The models exhibited were:—(1) Two in plaster of Paris of surfaces with a cubic and biquadratic equation respectively. (2) Of a surface described by a generating line always at right angles to a tangent at a point on a fixed circle. The point moves round the circle at an angular rate twice that at which the generating line turns about the tangent, so that the two sides of the surface are continuous. The surface contains, besides the generating lines, two straight lines, viz., the axis, *i.e.*, the line through the centre of the circle at right angles to its plane, and the intersection, *i.e.*, the straight line in which the surface cuts itself. (3) A number of models showing how three interlocked surfaces may be applied to (*a*) a cylinder and (*b*) an anchor ring.

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2. *Interim Report of the Committee on Tables of Mathematical Functions.*

The Committee intend to present a report at the next meeting of the Association.

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3. *Interim Report of the Committee on Tables connected with the Pellian Equation.*

The Committee intend to present a report at the next meeting of the Association.

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4. *Note on the Glissettes of an Ellipse and of a Hyperbola.* *By* Professor P. G. Tait, *Sec.R.S.E.*

The author exhibited metallic discs constructed for the purpose of illustrating the singular theorem that the curve, described by any point in the plane of an ellipse, which slides between rectangular guides, can be described by a definite

point in the plane of a corresponding hyperbola which slides between rectangular guides, generally inclined to the former.

The theorem takes a curiously interesting though obvious form in the simplest case, viz., when the ellipse is a finite straight line; and then the apparatus also takes a correspondingly simple form.

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5. *A Curious Point Connected with the Parallel Axiom.* *By* Professor CHRYSTAL.

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6. *On Conjugate Circle Groups.* *By* Lieut.-Colonel ALLAN CUNNINGHAM, *R.E., Fellow of King's College, London.*

When three circles whose centres are Ω, ω, Ω' are coaxal, and are placed so that ω bisects the distance $\Omega\,\Omega'$, the two circles Ω, Ω' are said to be conjugate with respect to the circle ω. With several conjugate pairs it is shown that—

1. The join of the centres of two non-conjugate circles is equal and parallel to the join of the centres of their conjugates.

2. The radical axis of two non-conjugate circles is also that of their conjugates.

3. The radical centre of any three circles is also that of their conjugates.

A group of four conjugate pairs of circles, arranged in a certain way about a triangle A B C, is styled a *Bi-conjugate Quartett.* Take as example the eight circles which cut three given circles A, B, C, orthogonally or diametrally.

In this case, in general, the twenty-four pairs of non-conjugate circles have only nine radical axes, and the fifty-six triplets of circles have only thirteen radical centres; the sides and vertices of the triangle A B C are the most important, each side being the radical axis of four pairs, and each vertex the radical centre of eight triplets.

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7. *A Method of Finding the Logarithms of Large Numbers.* *By* Rev. Dr. T. SMITH.

MONDAY, AUGUST 8.

The following Reports and Papers were read:—

1. *Report of the Committee on the Ultra-Violet Rays of the Solar Spectrum.* See Reports, p. 74.

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2. *On the Construction of the New Physical Laboratory at Groningen, Holland.* *By* Professor P. H. SCHOUTE.

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3. *Interim Report of the Committee on Measuring Optical Constants.*

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4. *On a Method of Determining Thermal Conductivities.* *By* CHARLES H. LEES, *M.Sc.*

This method has been designed to determine the conductivities of liquids when only small quantities are available. It follows closely the definition of conductivity. A cylinder of thin copper, about 3 cm. diameter and 4 cm. high, has a copper base 3 mm. thick, and is filled with water in which is placed a coil of wire

through which a current of electricity can be sent. Below this cylinder is placed another provided with a copper disc at the top, this cylinder being kept cool by the passage of a stream of cold water through it. Between the two copper discs comes the layer, about 1 mm. thick, of the liquid the conductivity of which is to be determined. The temperatures of the copper discs are determined by means of thermo-junctions. A current is sent through the heating coil till the temperature of the heating cylinder, as indicated by a thermometer in it, is about 5° above that of the cooler. By adjusting the current through the coil this temperature excess can be maintained for any required time. The temperatures of the copper discs are during this time determined, and from their difference and the amount of energy supplied by the current to the heater, it would be possible, if there were no loss of heat due to radiation, to determine the thermal conductivity of the liquid between the discs. By another experiment this loss can, however, be determined and subtracted from the total loss, and thus the conductivity found. In another form of the apparatus this correction is got rid of by surrounding the heater with an annular vessel, separated from it by a layer of non-conductor. This outer vessel is also provided with a heating coil, and by means of rheostats in circuit the temperature of both heaters, as indicated by thermometers in them, is kept the same. The energy supplied to the inner heater is then merely that necessary to compensate the loss of energy due to conduction through the layer of liquid at the base of the cylinder, so that the conductivity of the liquid is readily found from the observations.

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5. *Interim Report of the Committee on a National Physical Laboratory.*

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6. *A Discussion on a National Physical Laboratory was opened by* Professor Oliver J. Lodge, *F.R.S.*

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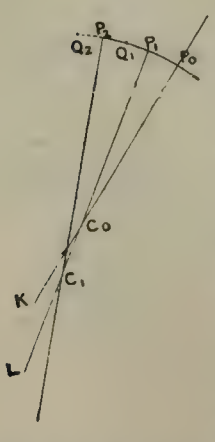
7. *On Graphic Solution of Dynamical Problems.* *By* Lord Kelvin.

The method of drawing meridional curves of capillary surfaces of revolution, described in 'Popular Lectures and Addresses,' vol. i., 2nd edition, pp. 31–42, and illustrated by woodcuts made from large scale curves, worked out according to it with great care by Professor Perry when a student in the Natural Philosophy Class of Glasgow University, suggests a corresponding method for the solution of dynamical problems.

Fig. 1.



In dynamical problems regarding the motion of a single particle in a plane, it gives the following plan for drawing any possible path under the influence of a force of which the potential is given for every point of the plane. Suppose, for example, it is required to find the path of a particle projected in either direction, with any given velocity, in any given direction through any given point P_0 (fig. 1). Calculate the normal component force at this point; and divide the square of the velocity by this value, to find the radius of curvature of the path at that point. Taking this radius on the compasses, find the centre of curvature, C_0, in the line, P_0K, perpendicular to the given direction through P_0, and describe a small arc, $P_0P_1Q_1$, making P_1Q_1 equal to about half the length intended for the second arc. Calculate the altered velocity for the position Q_1, according to the potential law; and, as before for P_0, calculate a fresh radius of curvature for Q_1 by finding the normal component force for the altered direction of normal and for the velocity corre-

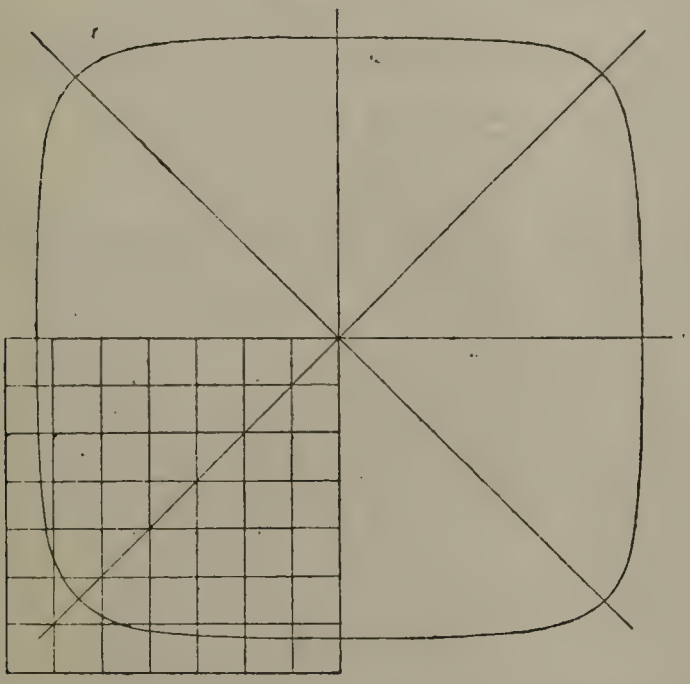
sponding to the position of Q_1. With this radius, find the position of the centre of curvature, C_1, in P_1C_0L, the line of the radius through P. With this centre of curvature, and the fresh radius of curvature, describe an arc $P_1P_2Q_2$ making P_2Q_2 equal to about half the length intended for the third arc; calculate radius of curvature for Q_2; draw an arc $P_2P_3Q_3$; and continue the procedure. This process is well adapted for finding orbits by the 'trial and error' method described in my article 'On Some "Test Cases" of the Maxwell-Boltzmann Doctrine regarding Distribution of Energy,' sect. 13; 'Proc. Royal Soc.', June 11, 1891.

The accompanying curve (fig. 2) has been drawn with great care, and with very interesting success, in the 'trial and error' method of finding the first and simplest orbit, by my secretary, Mr. Thomas Carver, for the case of motion defined by the equations

$$\frac{d^2x}{dt^2} = -yx^2.$$

$$\frac{d^2y}{dt^2} = -xy^2.$$

FIG. 2.



The initial point P_0 was taken on one of the lines cutting the axes of x and y at 45°, and at first at a random distance from the origin. A trial curve was worked according to the method described above, and was found to cut the axis of y at an oblique angle. Other trial curves, with unchanged energy-constant, were worked from initial points at greater or less distances from the origin, until a curve was found to cut the axis of y perpendicularly. This curve is one-eighth part of the orbit; and is shown in fig. 2 repeated eight times, in order to complete the orbit which is symmetrical on the two sides of the axes of x and y.

As an interesting case of motion related to the Lunar Theory, suppose the mass of the moon be infinitely small in comparison with the mass of the earth, and the earth and sun to have uniform motions in circles round their centre of gravity. Let (x, y) be co-ordinates of the moon relative to OX in line with the sun, outwards, and OY perpendicular to it in the direction of the earth's orbital motion. The well-known equation of motion relatively to revolving co-ordinates gives, for

the equations of the moon's motion, if a denote the distance from O (the earth) of the centre of gravity of the sun and earth,

$$\frac{d^2x}{dt^2} - 2\omega\frac{dy}{dt} - \omega^2(a+x) = -\frac{dV}{dx} \quad . \quad . \quad . \quad . \quad (1),$$

$$\frac{d^2y}{dt^2} + 2\omega\frac{dx}{dt} - \omega^2 y = -\frac{dV}{dy} \quad . \quad . \quad . \quad . \quad (2),$$

where V is the potential of the attractions of the sun and earth on the moon, and ω the angular velocity of the earth's radius vector. From this we find, for the relative-energy equation

$$\tfrac{1}{2}\left(\frac{dx^2}{dt^2}+\frac{dy^2}{dt^2}\right) = \mathrm{E} + \tfrac{1}{2}\omega^2(x^2+y^2) - \mathrm{V} \quad . \quad . \quad . \quad . \quad . \quad (3),$$

where E denotes a constant, and for the relative-curvature equation

$$\frac{dxd^2y - dyd^2x}{\left(dx^2+dy^2\right)^{\frac{3}{2}}} = -2\omega\frac{dt}{\left(dx^2+dy^2\right)^{\frac{1}{2}}} + \frac{\mathrm{N}dt^2}{dx^2+dy^2} \quad . \quad . \quad . \quad . \quad (4),$$

where N denotes the component perpendicular to the path, of the resultant of (X,Y) with

$$\mathrm{X} = \omega^2(x+a) - \frac{dV}{dx} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5),$$

$$\mathrm{Y} = \omega^2 y - \frac{dV}{dy} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6).$$

Hence if q denote moon's velocity and ρ the radius of curvature of her path, relatively to the revolving plane XOY, we have

$$\tfrac{1}{2}q^2 = \mathrm{E} + \tfrac{1}{2}\omega^2(x^2+y^2) - \mathrm{V} \quad . \quad . \quad . \quad . \quad . \quad (7),$$

and

$$\frac{1}{\rho} = \frac{-2\omega}{q} + \frac{\mathrm{N}}{q^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8).$$

Calling S the sun's mass, and a his distance from the earth, and supposing the earth's mass infinitely small in comparison with the sun's, we have

$$\frac{\mathrm{S}}{a^2} = \omega^2 a \quad . \quad . \quad . \quad . \quad . \quad . \quad (9),$$

and therefore

$$-\mathrm{V} = \frac{\omega^2 a^3}{\left[(a+x)^2+y^2\right]^{\frac{1}{2}}} + \frac{m}{r} \quad . \quad . \quad . \quad . \quad (10),$$

where m denotes the earth's mass, and $r = \sqrt{(x^2+y^2)}$.

Hence

$$-\mathrm{V} = \tfrac{1}{2}\omega^2(2a^2 - 2ax + 2x^2 - y^2) + \frac{m}{r} \quad . \quad . \quad . \quad (11).$$

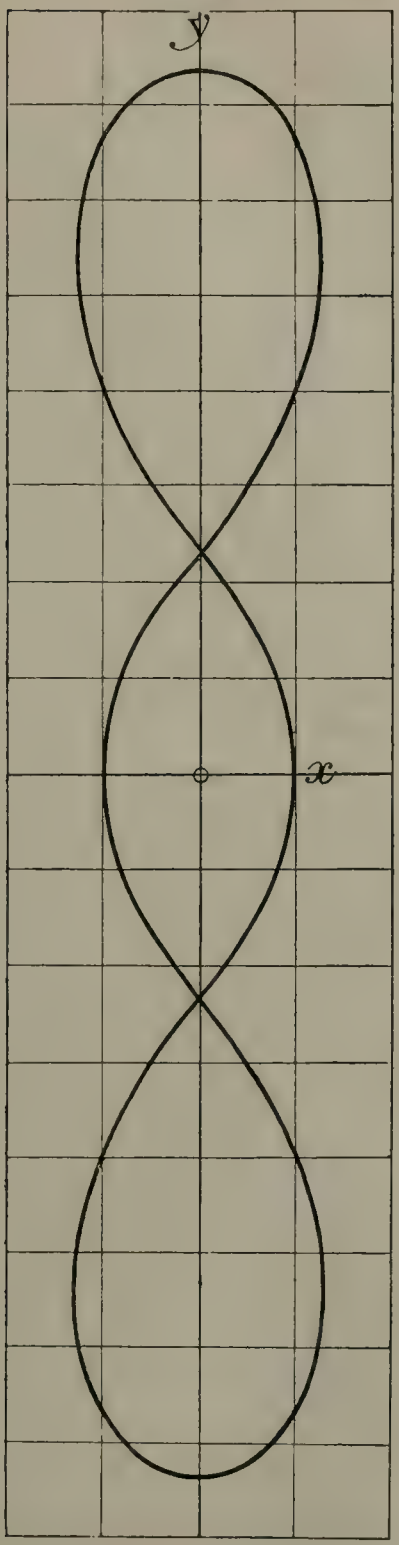
With this and with $\omega = 1$ and $m = b^3$, for simplicity in the numerical work which follows, we have

$$\frac{d^2x}{dt^2} - 2\frac{dy}{dt} = \mathrm{X} = x\left(2 - \frac{b^3}{r^3}\right) \quad . \quad . \quad . \quad . \quad . \quad (12),$$

$$\frac{d^2y}{dt^2} + 2\frac{dx}{dt} = \mathrm{Y} = -y\frac{b^3}{r^3} \quad . \quad . \quad . \quad . \quad . \quad (13),$$

$$q^2 = 2\mathrm{E} + 3x^2 + \frac{b^3}{r} \quad . \quad . \quad . \quad . \quad . \quad . \quad (14),$$

FIG. 3.



and

$$\rho = \frac{q^2}{N - 2q} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15).$$

From equations (12) and (13), G. W. Hill has, with four different values of E, found x and y explicitly in terms t, for the particular solution in each case which gives the simplest *orbit* (relatively to the revolving plane XOY), of which the one which presents the greatest deviation from the well-known 'variational' oval of the elementary lunar theory is a symmetrical curve with two outwardly projecting cusps corresponding to the moon in quadratures. He supposed this to be the most extreme deviation from the variational oval possible for an orbit surrounding the earth. Poincaré, in his 'Méthodes Nouvelles de la Mécanique Céleste,' 1892, p. 109, admiring justly the manner in which Hill has thus 'si magistralement' studied the subject of finite closed lunar orbits, points out that there are solutions corresponding to *looped* orbits, transcending Hill's, wrongly supposed extreme, cusped orbit. Mr. Hill tells me that he accepts this criticism. The labour of working out a fairly accurate analytical solution for any of Poincaré's looped orbits, by Hill's method, would probably be very great. I have therefore thought it might interest others besides ourselves to apply my graphic method to the drawing of at least one of Poincaré's looped orbits, in our Physical (and Arithmetical) Laboratory in the University of Glasgow. Fig. 3 represents a looped orbit, which has been worked out accordingly by Mr. Magnus Maclean, Chief Official Assistant of the Professor of Natural Philosophy from the equations (14), (15) above.

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8. *Reduction of every problem of Two Freedoms in Conservative Dynamics, to the drawing of Geodetic Lines on a Surface of given Specific Curvature.* *By* Lord KELVIN, *Pres.R.S.*

1. Any conservative case of two-freedom motion is proved to be reducible to a corresponding case of the motion of a material point in a plane.

2. In plane conservative dynamics, with any given value for the energy constant, E, the resultant velocity, q, at any point (x, y) is a known function of (x, y), being given by the equation

$$q^2 = 2(E - V) \quad . \quad . \quad . \quad . \quad (1)$$

where V denotes the potential at (x, y); and every problem depends on drawing lines for which $\int q\,ds$ (the Maupertuis 'action') is a minimum.

3. Considering any part, S, of the infinite plane, find a surface, S′, such that any infinitesimal triangle A′ B′ C′ drawn on it has its sides equal to $\frac{q}{q_0}$ of those of a corresponding triangle A B C in the field, S, of our plane problem; q_0 denoting the value of q at any particular point (x_0, y_0) in the plane. By the principle of least action we see instantly that the lines on S′, corresponding to paths on S, are geodetic. Thus the *adynamic* case of motion of a particle on S′ is found as a perfect and complete representative of the motion on the plane surface S, under force with any arbitrarily given function, V, for its potential, and any particular given value, E, for the total energy of the moving particle.

4. It is proved easily that the surface, S′, to be found according to §3, exists; and that its specific curvature (Gauss's name for the product of its two principal curvatures) at any point is equal to

$$\frac{q_0^2 \nabla^2 \log q}{q^2}.$$

5. Examples are given of the finding of S′. As one example, illustrating the practical usefulness of this method in dynamics, the problem of the parabolic

motion of an unresisted projectile is reduced to the drawing of geodetic lines on a certain figure of revolution of which the explicit equation,

$$y = \int dx \sqrt{(x^4 - 1)},$$

is expressed in terms of elliptic functions.

TUESDAY, AUGUST 9.

The following Reports and Papers were read:—

1. *Report of the Committee on Electrolysis.*—See Reports, p. 72.

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2. *Report of the Committee on the Discharge of Electricity from Points.* See Reports, p. 72.

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3. *A Magnetic Curve Tracer. By* Professor J. A. Ewing, *F.R.S.*

The instrument traces complete curves for cyclic or other processes of magnetisation. The material whose magnetisation curve is to be determined is arranged to form a magnetic circuit with a narrow gap in it, and in this gap a conducting wire is tightly stretched. A constant current passing along this wire causes it to sag up or down across the lines of force in the gap. Its movements, which are proportional to the magnetism of the magnetic circuit, are communicated to a mirror which is pivoted on a single needle-point, and is capable of being deflected in azimuth as well as in altitude. The sag of the wire gives the mirror movement in altitude. At the same time the mirror receives azimuthal deflection from another stretched wire, which is stretched in a narrow gap between the poles of another magnet. This second wire carries the variable current which is used to produce the magnetisation of the first magnetic circuit, and the magnetic field in which it is stretched is kept constant. Its movements are therefore proportional to the magnetising current of the main circuit. In this way the mirror receives deflections in azimuth which are proportional to the magnetising force as well as deflections in altitude which are proportional to the magnetisation. Complete curves for such operations as double reversal of magnetism are readily traced out, and may be photographed by allowing the spot of light to fall on a sensitive plate, or may be marked by following its movements on a sheet of paper with a pencil. The instrument allows all the phenomena of magnetic hysteresis to be examined with great readiness. The magnetic circuit which is under test is arranged in such a way that the specimens of metal composing it may be quickly removed and replaced by others. The instrument thus forms a practical magnetic tester capable of workshop use in determining the magnetic qualities of any samples of iron or steel. When the magnetic circuit is laminated the instrument allows magnetic reversals to be performed with sufficient speed to make the mirror trace out a continuous line of light upon the screen. For very high speeds a pair of independent mirrors may be preferred, arranged to give the beam of light its two components of motion by successive reflexion. The arrangement is equivalent to the combination of an extremely dead-beat galvanometer with an equally dead-beat magnetometer. The galvanometer portion may be used alone in cases demanding the use of a current-measuring instrument with a very high frequency of free oscillation; and by making the magnetic fields in both gaps constant, and sending variable currents through both the stretched wires, the relations of the currents as to period and phase may be studied.

The instrument exhibited is sufficiently dead-beat to allow cycles of magnet-

isation to be gone through at any frequency up to twenty cycles per second without causing any serious disturbance of the diagram to arise from the inertia of the working parts, a continuous-current commutator being used to effect the reversals. The general character of the diagram is the same at this speed as at any lower speed. The presence of an air-gap in the magnetic circuit may be allowed for by giving the diagram which shows the relation of magnetism to magnetising force a shear backwards through such an angle as will compensate for the shearing effect of the air-gap. This can be automatically done in the magnetic curve tracer by placing the fixed point about which the mirror turns in such a position that the two components of motion are inclined not at right angles at an angle which exceeds a right angle by the amount of the shear that is required to rectify the diagram.

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4. *On a Magnetic Balance and its Practical Use.* *By* Dr. H. E. J. G. du Bois.

This instrument is intended to afford an easy and reliable means of determining magnetic curves or hysteresis loops of materials used in machine construction. One test-piece is cut to 15 cm. length, and by means of a template is best turned down so as to have 1 cm.^{2} cross-section; this obviates all further calculation. Its circuit is completed by two end-pieces and a massive yoke, excentrically supported; the resulting moment is compensated by weights sliding on a divided horizontal scale, on which the values of the magnetisation are directly read in absolute units. The value of the magnetising field is given by multiplying the current in the coil into ten. In plotting the results abscissæ are measured from an 'instrumental directrix,' inclined towards the left from the axis of ordinates. The apparatus was exhibited to the Section, as well as half a dozen test-pieces, and the curves obtained for them.

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5. *Report of the Committee on Electrical Standards.*—See Reports, p. 132.

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6. *On Wire Standards of Electrical Resistance.* *By* Dr. St. Lindeck. See Reports, p. 139.

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7. *On the Clark Cell.* *By* Dr. K. Kahle.—See Reports, p. 147.

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8. *A Discussion on the Nomenclature of Units was opened by* Professor Oliver J. Lodge, *F.R.S.*

[In connection with this discussion a report on units was read by M. C. E. Guillaume. This communication was ordered by the General Committee to be printed *in extenso*.—See Reports, p. 165.]

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9. *On the Dielectric of Condensers.*[1] *By* W. H. Preece, *F.R.S.*

Artificial cables are very useful adjuncts to the laboratory of the telegraph engineer. They not only enable him to experiment at his leisure, but they form very useful means to test and compare high-speed and delicate telegraph apparatus, and especially telephones. I have one, made some years ago, which has been in incessant use, composed of fifty-four inductionless coils of insulated copper wire, each giving 33 ohms' resistance, and having a condenser of one microfarad capacity

[1] Lord Kelvin proposes to call this useful instrument a 'Leyden,' because the term 'condenser' is applied to other more appropriate mechanical and physical apparatus.

at the juncture of each pair of coils and one at the termination of the series. This represented a circuit of a total capacity (K) of 54 microfarads, and of a total resistance (R) of 1782 ohms, the KR being 96228. This was equivalent to an ordinary submarine cable of 162 nauts length. It was not sufficient for our growing wants, and another similar set was recently made, of the same dimensions and materials, and in the same way. But it did not give the same results. The resistances were exactly the same, but the individual capacities differed. This difference, of nearly 5 per cent., was, of itself, of no practical consequence for the particular purpose for which the cable was constructed, but, on carefully comparing the two 'cables' with telephones, it was found that with the same nominal KR the one gave 30 per cent. better results than the other. This was a surprising and unexpected result. I thought it might be due to inductance, but none, neither *self* nor *mutual*, could be detected.

The insulation, taken after one minute's electrification, of each was:—

Old cable 172·8 megohms per naut,
New „ 82·8 „ „ „

so that the difference was in favour of the old one. But the electrification of the new one was much superior to that of the old one. The difference in resistance reading between the first and second minute of the former was $\frac{1}{20}$th of that of the latter.

Each cable was then rapidly charged and discharged 1,200 times, at varying rates, with an E.M.F. of 40 volts, and the cumulative remaining charge in each case read by deflection on a Thomson galvanometer. This was done by passing a 10-foot length of perforated slip through a Wheatstone's automatic transmitter. The following are the results:—

Number of Discharges per Second	Discharge		Percentage Difference
	New	Old	
20	46	28	39
40	86	55	36
80	151	100	33
120	200	136	32
160	237	168	29

This clearly shows that the effect is due to absorption. Electrification, polarisation, and absorption are phases of electrolytic work done by the current upon the dielectric. The material is slightly decomposed by the leakage current, a counter E.M.F. is set up, which increases the apparent resistance (electrification), it gives a current of discharge reverse to that of charge (polarisation), it absorbs a quantity of electricity, the undissipated part of which is recovered as a discharge current. The condenser acts, in fact, like a secondary cell.

We are now using better paper than formerly—that made from the best linen rags, thinner tinfoil, and better wax, the best refined unadulterated white paraffin, having a melting-point of from 125° to 128° F. Resin was formerly mixed with the wax, and when hot and liquid it was painted on the paper with a brush. The paper is now thoroughly dried, and well saturated with wax, by soaking under pressure, so as to get rid of all the moisture. Hence there is less electrification and less absorption, and consequently less retardation, and hence the superiority of the new 'cable.' In the old type of condenser we observed a variation of capacity due to temperature, but in the new type this has disappeared. This effect of absorption on the effective capacity of the condensers, and of insulated conductors, is new to me, and, as it may be new to many others, I have thought it to be of sufficient interest to bring it before Section A.

It is a new term to be added to the equation of energy of compound circuits, and it has evidently a material influence upon the retardation of signals in long submarine cables. It has an equally important influence on the efficiency of tele-

phone circuits, and it accounts partially for the great difference in my KR law between the observed effects of aerial and those of subterranean, or submarine, conductors. The former are always much superior to the latter. This would be due to the absence of polarisation in air as well as to other electromagnetic and electrostatic causes. No work would be done on the molecules of air, no energy would therefore be absorbed, and no retardation of currents from this cause would ensue. An air dielectric is clearly the 'Holy Grail' of the electrician.

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10. *Earth-currents.* *By* W. H. PREECE, *F.R.S.*

The year 1892 has been remarkable in the number and severity of those electric storms which interfere so seriously with telegraphic communication. Unfortunately, observations made upon them on working circuits are rarely reliable. Their arrival and departure are sudden; they come when they are least expected, and they occur in busy hours, when the wires are fully occupied with more remunerative currents, and when the staff is fully engaged. Their presence, duration, and relative intensity are so exactly coincident with magnetic disturbances that the recorded observations in magnetic observatories of needle variations may be taken to indicate the same elements of earth-currents also, but they do not give their direction or their absolute intensity. Their general direction is determined by the simultaneous observation of many circuits running in many directions, and noting the lines of maximum and those of no disturbance. This gives the position of the equipotential planes on the surface of the earth, and the intensity of the currents gives the difference of potential between these planes.

I have not succeeded in obtaining definite facts to prove that these planes are perpendicular to the line joining the centre of the earth and the centre of the sun, but there is little doubt that it is so, for telegraph circuits running in this direction experience the maximum disturbances, while those running at right angles on the equipotential planes suffer no disturbance. Those that experience the maximum disturbance in the forenoon are not affected in the evening, and *vice versâ*.

The storms commenced on January 4, and they have been observed at frequent intervals since.

The great storms occurred on February 13, March 12, April 24–27, May 18, July 16.

The intensity of the maximum currents observed in England frequently exceeded ·045 ampère (or 45 milliampères), which much exceeds in strength the working currents. Hence ordinary telegraph working was paralysed, and we had to resort to metallic circuits and to the use of condensers to maintain telegraphic communication.

The effect of such currents on our railways might be positively dangerous, for they ring bells and reverse the block signals.

·045 ampère means ·54 volt per mile, so that the equipotential planes differing by 1 volt would have been placed about two miles apart.

These earth-currents, though variable, are always continuous, and give no indication of alternations.

The simultaneous appearance of auroræ shows that disturbances on the sun's photosphere, as indicated by sun-spots, produce electrostatic and electromagnetic effects on the earth's surface of enormous magnitude.

The appearance of earth-currents is invariably simultaneous over the whole globe.

Observers abroad would benefit science if they would record the maximum strength, in milliampères, of the currents received, the geographical direction of the terminal earths of the circuits affected and unaffected, the resistance in ohms of the circuits on which the currents are measured, and if they were to give the times of observation in Greenwich and not in local time.

11. *On the Physics of the Voltaic Arc.*
By Professor Silvanus P. Thompson, *F.R.S.*

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12. *Preliminary Note on the Temperature Variation of the Magnetic Permeability of Magnetite.* *By* Edwin H. Barton, *B.Sc.*, *and* W. Williams, *B.Sc.*

1. After being engaged for some time upon the 'Magnetic Survey of the United Kingdom,' Professor Rücker put forward his 'Theory of Terrestrial Magnetism' ('Proc. Royal Soc.,' vol. xlviii. June 19, 1890, 'Relation between Magnetic Permeability of Rocks and Regional Disturbances').

In connection with this theory it was desirable to ascertain the permeabilities of various rocks both at ordinary and high temperatures.

The investigation referred to in the present preliminary note is an instalment in this direction.

2. Professor Rücker proposed this undertaking, and indicated the plan to be pursued. It was then carried out under his supervision at the Royal College of Science, London, as follows:—

W. Williams worked out the theory of the method, calculated what coils would be suitable, and wound them accordingly.

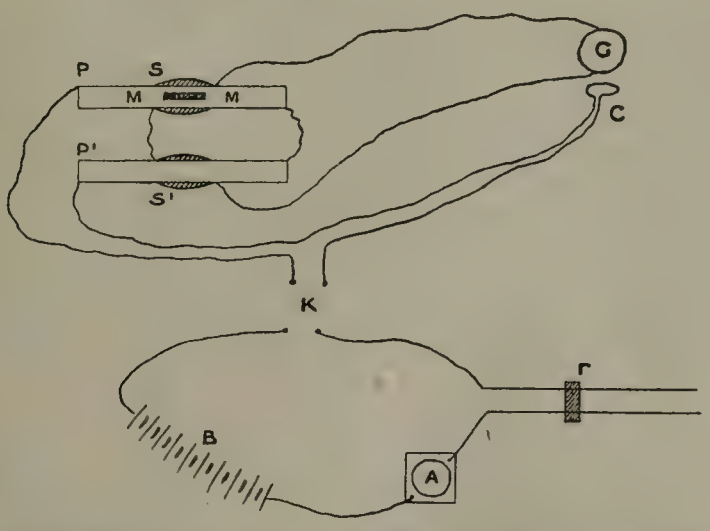
E. H. Barton arranged the apparatus, eliminated disturbances, took the observations, and plotted the results.

3. For measuring the susceptibility of the magnetite the ballistic method was adopted.

Since the specimen was to be exposed to high temperatures, the coil to receive it was insulated with asbestos paper, and wound upon a porcelain tube. The secondary coil was further insulated from the primary by two sheets of mica to obviate the probability of leakage between the two.

The temperature of the magnetite, when heated, was estimated from the consequent E.M.F. of a thermo-electric couple of platinum and osmium-iridium.

Fig. 1.



M M, Specimen of magnetite; P and S, primary and secondary coils, heated by gas stove (not shown in figure); P′ and S′, compensating coils; B, battery; A, ammeter; r, adjustable resistance; K, a 'Pohl's' commutator; C, compensating coil; G, highly sensitive low-resistance galvanometer.

One of the junctions was round the specimen of magnetite, and the other in a beaker of water. This couple was first calibrated by placing one junction in

melting ice, boiling water, and sulphur vapour respectively, the other junction being meanwhile at ordinary temperatures.

The arrangement adopted for obtaining the sulphur vapour and the temperature assigned to it were those published by Messrs. Callander and Griffiths.[1]

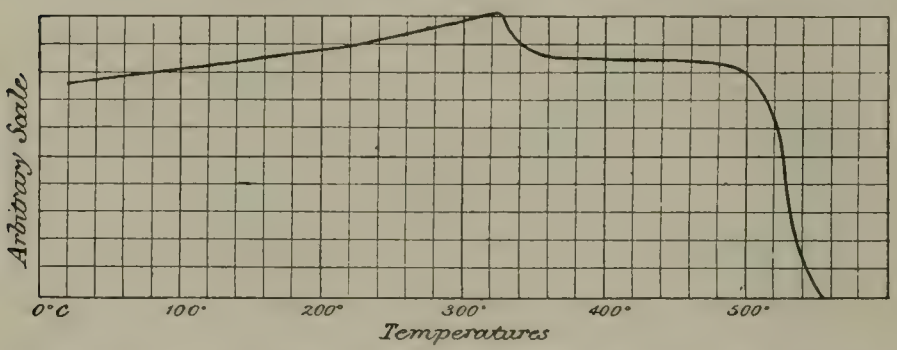
4. The electrical connections used for measuring the induction effects are diagrammatically represented below (fig. 2).

5. Eight distinct disturbances were dealt with. Some of them were eliminated, others measured, and the necessary correction applied when deducing the true effect due to induction.

6. The result obtained may be exhibited by a curve whose abscissæ are the temperatures of the magnetite, and whose ordinates are proportional to the induction effects due to its presence, the impressed magnetic field being constant.

Commencing at ordinary temperatures, it is seen, from the curve, that the susceptibility for the specimen used rose gradually at first with increase of temperature, reached a maximum at 325° C., then fell away, being zero at 557° C.

FIG. 2.—Curve showing the variation of the magnetic susceptibility of magnetite with temperature. Impressed magnetic field constant.



The sharp peak in the curve at 325° C., though apparently anomalous, was confirmed by a careful repetition of the measurements in that region. It cannot therefore be regarded as due to experimental errors.

7. The impressed magnetic field (treating the primary solenoid as infinitely long) was 4·8 c.g.s. units. The actual field within the specimen of magnetite (when cold) was of the order 3·4 c.g.s. units.

8. The determination of the absolute values of the permeability for the various temperatures is not yet completed. When this has been done we hope to publish a fuller account of the methods and result of the investigation.

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13. *On the Spectrum of Liquid Oxygen, and on the Refraction Indices of Liquid Oxygen, Nitrous Oxide, and Ethylene.* *By* Professor G. D. LIVEING, *F.R.S.*, *and* Professor J. DEWAR, *F.R.S.*

WEDNESDAY, AUGUST 10.

The following Papers were read:—

1. *Interim Report of the Committee on Recalescence.*

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[1] 'On a Determination of the Boiling Point of Sulphur, and a Method of Standardising Platinum Resistance Thermometers by reference to it' (*Proc. Roy. Soc.*, vol. xlix., Dec. 18, 1890, p. 56).

2. *The Magnetic Curve.*
By the Rev. F. J. Smith, *M.A.*

By the 'magnetic curve' is here meant a stream-line in plane space due to a source and an equal sink, or to two equal sources. The author gives a short description of a method for drawing it by the use of linkages. Suppose that the source and sink are in a horizontal line at distance a apart. Attach two strings of equal length—one to the point at which the source is fixed, another to the point at which the sink is placed. Attach the other ends of these strings to the ends of a rod, whose length is equal to a, which can move in a horizontal line—the one string being attached to those ends of the two equal lines of length a which are nearest together, while the other is attached to the extreme ends. If the middle points of the cords be now weighted, and the movable line of length a be slid along horizontally, the point of intersection of the lines proceeding from the source and sink traces the required curve. If the middle point of the cord attached to the near ends of the lines of length a be attached to a string which passes round a pulley placed vertically over the middle point of the cord (so that the cord is stretched upwards instead of downwards) the intersection of the cord, which is attached to one of the fixed points, with the prolongation of the other cord, which is attached to the other fixed point, traces a stream-line due to two equal sources placed at these points.

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3. *Certain Volume Effects of Magnetisation.*
By Professor Cargill G. Knott, *D.Sc.*, *F.R.S.E.*

Five tubes of Swedish iron and five tubes of Bessemer steel were made of the same length (45·7 cm.) and of the same external diameter (1·92 cm.). The tubes were distinguished in each case by number, No. 1 having the widest bore, and No. 5 the narrowest bore. The diameters of the bores were in order, 3·19, 2·56, 1·93, 1·40, and 0·7 cm. Each tube was closed below, and into the upper end a nut screwed tightly, through a perforation in which issued a fine capillary glass tube. The nut was adjusted under water, so that the whole interior space of the metal tube was filled with liquid, and also part of the glass tube. When the tube was set vertically in the heart of the magnetising coil, the changes of volume were measured by the motions of the liquid meniscus in the capillary tube. These motions were observed by a powerful microscope.

The changes of volume were observed as each field was applied and removed, first in one direction and then in the other. If this alternation of direction of field were not adopted the metal tube got into a magnetically biassed condition. This magnetic bias was particularly noticeable when the field applied was smaller than the field that had just been previously applied. After exposure to a high field the tube could be neutralised by reversals in the well-known fashion.

In the following brief abstract of the broad effects, the iron tubes are named by Roman numerals, and the steel ones by Arabic, and the dilatation is regarded as positive when the core space enlarges, and negative when it contracts. Nos. I, 1, and 2, show negative dilatations in fields lower than from 100 to 200 c.g.s. units, and positive dilatations in higher fields. Nos. II., III., and IV. (all iron) give negative dilatations throughout, up to the highest fields used. No. V. begins with positive dilatation in very low fields, but in moderate and high fields behaves like II., III., and IV. In IV. and V. the negative dilatation increases rapidly in high fields and shows no sign of reaching a limit up to a field of 1,400 units. No. 3 (steel) begins with positive dilatation in low fields, and continues so throughout, approaching a limit as the 1,400 field is reached. Nos. 4 and 5 begin with positive dilatations, attain a sharp maximum, and above fields of 300 and 200 respectively show negative dilatations, which grow rapidly in higher fields as in the case of the iron tubes IV. and V. In the following scheme are given the measured values (multiplied by 10^7) of the dilatations for all the tubes in fields 100, 1,000, and in fields in which a maximum or minimum is obtained, if such a maximum or minimum exist. The values of these last-named fields differ for the different tubes, and

are not given ; but the scheme indicates where they come, whether below or above 100. In no case were they higher than 200 or lower than 50.

	Iron					Steel				
Field	I	II	III	IV	V	1	2	3	4	5
(Max. or min.)	−5				+ 2	− 5·5				
100	−3	−6·5	− 8·5	− 4	+ 0·5	− 2	−5·5	− 2	+ 3·5	+11·5
(Max. or min.)		−8	−19				−5·5		+ 3·5	+12
1,000	+4	−3·2	−17	−46	−83	+11·2	+6	−31	−59	−60?

A few experiments were made on the external change of volume of a few of the tubes, which were inclosed in a thin-walled brass tube. The brass tube yielded because of its thinness, so that the results were not certain. But there was no doubt that with the specimens of iron tried there were large changes of volume. Joule's nugatory result must have been peculiar to the kind of iron he worked with.

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4. *On Polarising Gratings.* By Dr. H. E. J. G. du Bois.

Very minute gratings made of silver wire of $\frac{1}{25}$ millimetre in diameter were found to polarise transmitted light perpendicularly to the wires. The amount of polarisation was found within a certain range to be inversely proportional to the apparent width of the clear spaces, and to increase with the wave-length, reaching 13 per cent. in one case for red light. The same effect was found with gratings scratched into thin platinum films. In collaboration with Dr. Rubens, the author then extended these researches to heat radiations beyond the red. It was found that the perpendicular polarisation reached a maximum near $\lambda = 100$ microcentimetres ; thence diminishing and vanishing near $\lambda = 200$. For greater wave-lengths the polarisation became parallel to the wires, and went on increasing with λ. The analogy of these phenomena with the polarisation of Hertzian radiations appears to be more than a superficial one. The authors by developing these preliminary experiments, by using still finer wires made of different metals and reaching longer waves, hope to contribute towards bridging over the considerable gap that still separates Hertzian electro-magnetic radiation from those radiations with which we are more intimately acquainted.

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5. *An Estimate of the Rate of Propagation of Magnetisation on Iron.* By Professor G. F. Fitzgerald, *F.R.S.*

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6. *Remarks on the Early Rise and Progress of Electrical Illumination.* By Dr. Alexander Keiller.

It was pointed out that in 1836 Mr. J. B. Lindsay, of Dundee, gave lectures on electricity accompanied with an exhibition of a constant electric light.

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7. *Report of the Committee on Electro-optics.*—See Reports, p. 157.

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8. *On Dispersion in Double Refraction due to Electric Stress.* By Dr. John Kerr.

This paper forms the appendix of the report on Electro-optics.—See p. 157.

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9. *Proof that Density of Illumination does not affect Absorption.* *By* W. Peddie, *D.Sc.*

When parallel rays of light pass through a medium which exercises no absorptive influence, the intensity of the light is not diminished as it proceeds. When the medium is absorptive, it is assumed as a basis for the theory of radiation that if the intensity of the light be reduced in a given ratio on passage through a given thickness of the medium, it will be further reduced in the same ratio on passage through an additional equal thickness. There is strong indirect evidence that this assumption is correct. Professor Stokes suggested long ago a direct method of testing the point. In his method the light is reflected at nearly perpendicular incidence from the surface of glass, and two equal portions of the absorbing medium are used—one being placed in the course of one half of the incident light, the other in the course of the other half after reflection. Assuming that reflection is not affected by intensity, we thus get a direct test of the question. The author has used diverging light passing through two double-image prisms, a plate of quartz being interposed between them, and a lens being used for the purpose of proper definition. By rotation of one diprism, and by varying the thickness of the quartz, we can match closely any colour of the absorbing medium, and also get the complementary colour. One portion of the absorbing medium is inserted in the course of one ray, the other in the course of the similarly coloured ray, but at a different distance from the point of divergence. Surface-coloured glass was used in the experiments described. No difference of absorption was evident, although the intensity varied from one to 1,000, and a change of intensity alone (unaided by colour comparison) of one part in 100 could be detected.

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10. *Physical Conditions of the Waters of the English Channel.* *By* H. N. Dickson, *F.R.S.E.*

Careful determinations of the value of Dittmar's 'D' for numerous samples obtained at different seasons of the year show that the waters of the English Channel are uniform and constant in composition, at least as far east as the Isle of Wight. The mean value of D was 1·4550, a result in exact agreement with that found by Dr. Gibson for water collected in the Moray Firth, which he believed had come from the Atlantic.

The normal distribution of temperature seems to be that in summer the coldest water, and in winter the warmest, is found in mid-channel—the difference decreasing in summer and increasing in winter as we go eastward. Excluding a thin surface layer, the temperature is nearly uniform at all depths.

The principal exception to this rule occurs in the west of Start Bay, where a mass of water, cut off from the general tidal circulation, is subject to peculiar temperature conditions through the want of mechanical mixing.

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11. *On the Analysis and Synthesis of Colour.* *By* J. W. Lovibond.

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12. *On the General Laws of Energetics.* *By* Professor W. Ostwald.

The mechanical law of the virtual velocities, or, more properly, of the virtual work, is only a special case of a much more general law, holding good for all forms of energy except radiant energy. The condition of equilibrium of every energetic system can be found by summing up the virtual or correlative variations of the various forms of energy and putting the sum equal to zero. In order to express these virtual variations each energy must be written as a product of two factors—its capacity and its intensity.

As this calculus leads to the same results as those obtained up to the present by the application of the second law of thermodynamics, it is possible to prove that this second law is another case of the same general law of energetics, which

the author proposes to call the second law of energetics, the law of conservation of energy being the first law. This second law may be expressed in words in the following way: *A perpetuum mobile of the second order is impossible.* By a perpetuum mobile of the second order is meant an engine by means of which energy in equilibrium (*e.g.*, heat of constant temperature, or electric energy of constant potential) could be converted into work or some other form of energy.

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13. *On a Delicate Calorimeter.* *By* J. A. Harker, *D.Sc.*, *and* P. J. Hartog, *B.Sc.*

The authors have devised a calorimeter similar in principle to the Bunsen ice-calorimeter, but in which the ice is replaced by pure solid acetic acid. This substance melts at about the normal temperature of rooms, and, moreover, yields a considerably larger volume change per calorie than ice. The instrument will, it is hoped, prove specially useful for thermo-chemical measures with small quantities of material, and for physiological work.

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14. *Some Notes connected with the Electromotive Force of a Secondary Battery.* *By* Dr. J. H. Gladstone, *F.R.S.*, *and* W. Hibbert.

It has been recently shown by the authors that the changes in E.M.F. in a secondary battery depend mainly on the strength of the sulphuric acid that is against the working surfaces of the plates. If both plates be immersed in the strongest acid the E.M.F. is 2·60 volts. On continuing the investigation the authors have just found that, while lead against lead peroxide in pure water gives 1·36 volt, lead in water against lead peroxide in the strongest sulphuric acid gives 0·32 volt, and lead peroxide in water against lead in the strongest sulphuric acid gives 0·89 volt. The sum of these is 2·57 volts, nearly the same as the figure given above. By Lord Kelvin's thermo-electrical law it may be calculated that when both plates are immersed in the strongest sulphuric acid the E.M.F. will be 2·62 volts, and when immersed in water 1·35 volt. This is in close agreement with experiment. For intermediate strengths, however, theory and experiment do not equally coincide. The authors are at present examining this point, and have found that the E.M.F. increases when the temperature rises, and they have made a determination of the temperature coefficient, using a 14·7-per-cent. acid, and find it 0·0136 volt per degree of temperature.

Section B.—CHEMICAL SCIENCE.

President of the Section—Professor Herbert McLeod, F.R.S., F.C.S.

THURSDAY, AUGUST 4.

The President delivered the following Address:—

In endeavouring to prepare myself to properly fulfil the duties of President of this section, to which I have been elected, and for which honour I am much indebted to the council and members of the Association (although I am only too well aware that the position might have been more efficiently filled by many others), I naturally looked at the reports of the previous meetings held in Edinburgh in 1834, 1850, and 1871, and it appears that on the first two occasions an address was not given by the President, a custom the discontinuance of which I have, at the present moment, much reason to regret.

At the meeting in 1834 a committee was appointed, consisting of Dr. Dalton, Dr. Hope, Dr. T. Thomson, Mr. Whewell, Dr. Turner, Professor Miller, Dr. Gregory, Dr. Christison, Mr. R. Phillips, Mr. Graham, Professor Johnston, Dr. Faraday, Professor Daniell, Dr. Clark, Professor Cumming, and Dr. Prout, to report at the next meeting their opinion on the adoption of a uniform set of chemical symbols, Dr. Turner to be secretary.

In the following year the report contains: 'Report of the Committee on Chemical Notation. Dr. Turner, the chairman of the committee appointed to take into consideration the adoption of a uniform system of chemical notation, made a report to the following effect:—

'1. That the majority of the Committee concur in approving of the employment of that system of notation which is already in general use on the Continent, though there exists among them some difference of opinion on points of detail.

'2. That they think it desirable not to deviate in the manner of notation from algebraic usage except so far as convenience requires.

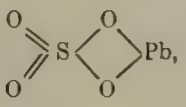
'3. That they are of opinion that it would save much confusion if every chemist would always state explicitly the exact *quantities* which he intends to represent by his symbols.

'Dr. Dalton stated to the Chemical Section his reasons for preferring the symbols which he had himself used from the commencement of the atomic theory in 1803 to the Berzelian system of notation subsequently introduced. In his opinion regard must be had to the arrangement and equilibrium of the atoms (especially elastic atoms) in every compound atom, as well as to their number and weights. A system either of *arrangements* without *weights*, or of *weights* without *arrangements*, he considered only half of what it should be.'

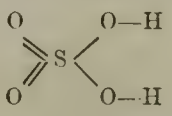
We can all sympathise with the members of the Section of 1834 in their desire to obtain a uniform system of chemical notation, for at that time several very different systems seem to have been in use. Although the report is a short one, it probably directed the attention of chemists to the desirability of avoiding confusion by the use of various systems, and since that period many advances have been made.

There is now little necessity for every chemist to 'state explicitly the exact *quantities* which he intends to represent by his symbols' for the accurate determinations of atomic weights by many chemists—and we must not omit to mention the work of Stas (whose death we have had to deplore since the last meeting of the British Association)—have given us a series of numbers which are in the hands of all chemists, so that, except in the cases where great refinement is requisite (or when the atomic weight has not been universally accepted) there is no need to state the values of the symbols.

That great advances have been made in chemical notation is well known to all; even in my own short experience I have had to learn several different methods. When I began to work at chemistry I was told that sulphate of lead was to be expressed by the formula PbO,SO_3. Hofmann taught me that it should be $PbSO_4$; then Gerhardt doubled the atomic weights of oxygen and sulphur, and the formula became Pb_2SO_4; Cannizzaro showed that the atomic weight of lead should also be doubled, and the formula again became $PbSO_4$, but representing twice as much as formerly; then Frankland taught me to write SO_2Pbo'' as the expression of the graphic formula—



which not only states that the compound contains 207 of lead, 32 of sulphur, and 64 of oxygen, but that the sulphur is hexad, and is combined with two atoms of dyad oxygen, and with a dyad compound radical containing one atom of lead and two of oxygen; and of all the formulæ just given this is the only one which satisfies the requirements which Dalton thought necessary in 1835, namely, to indicate not only the weights of the elements present, but also their arrangement. It may be objected that we do not know that this formula really represents the arrangements of the atoms in plumbic sulphate, but there can be very little doubt that the four atoms of oxygen in the compound are not all in the same condition, for if we examine the properties of sulphuric acid (from which the sulphate of lead is derived by the replacement of the hydrogen by lead), we find that two of the atoms of oxygen are more closely associated with the hydrogen than are the other two, and as there is some evidence, although perhaps not very conclusive, that sulphur may be capable of combining with six monad atoms, although no such compound is yet known, it does not seem unreasonable to suppose that sulphuric acid is really—



What the nature of the attraction that holds the atoms together may be is not known, but it is more probably of a character similar to that of gravity which holds together sun and planets than of the nature of cohesion which would hold the atoms rigidly together; the atoms in each molecule are therefore most probably in a state of rotation around, or of vibration to and from, the central atom which holds them together. The pictorial representation in a plane does not therefore truly express the position of the atoms, but merely the relations existing between them. In organic chemistry the use of formulæ expressing such a relation has

become indispensable, and in inorganic chemistry I believe such a system is very useful.

Recently this system has been found insufficient for the requirements of organic chemistry, and recourse has been had to the figure of a tetrahedron to represent the atom of carbon, other atoms being attached to the solid angles; in this way the position of the atoms in space is more or less expressed.

There are many cases, however, in which the atomicity theory fails us. At first it seemed probable that the atomicity of an element varied in pairs of attractions, that is, an element might be monad, triad, or pentad, but not dyad or tetrad; or it might be dyad, tetrad, or hexad, but not triad or pentad; but some great difficulties have been encountered. Thus nitrogen, which is pentad in ammonic chloride and triad in ammonia, forms the compound nitric oxide, NO, in which it would appear to be dyad; it has been suggested, however, that in this body the nitrogen is really triad, and that it possesses a 'free bond.' Now the idea of a 'free bond' seems contrary to the principles of atomicity, since it is on the belief that such a free bond is impossible that the explanation of the existence of elementary molecules is founded, for it is said that when hydrogen is liberated two atoms unite to form a molecule, so that their mutual attractions may be satisfied. Nevertheless nitric oxide is a very active body, uniting readily with other substances, so the free bond seems to be on the look-out for other kinds of matter, but to have no attraction for the free bond of another molecule of nitric oxide. As the molecule of nitric peroxide is variable by alterations of temperature, being N_2O_4 at low and NO_2 at high temperatures, it seemed not impossible that at the ordinary atmospheric temperature nitric oxide was a simplified or dissociated molecule, and that if the temperature were sufficiently reduced it would be found that its molecule would be N_2O_2, and thus it would contain triad nitrogen without a free bond. The density of the gas has, however, been determined at a temperature as low as $-73°$, and the molecule is still NO. Another important exception to the variation of the atomicity of an element in pairs was furnished by the investigations of Sir Henry Roscoe on the chlorides of vanadium: this element, which, from analogy, should be a triad or a pentad, appears to form a chloride of the composition VCl_4. Again, the molecule of peroxide of chlorine is ClO_2, which would make chlorine a tetrad or the compound must have a free bond.

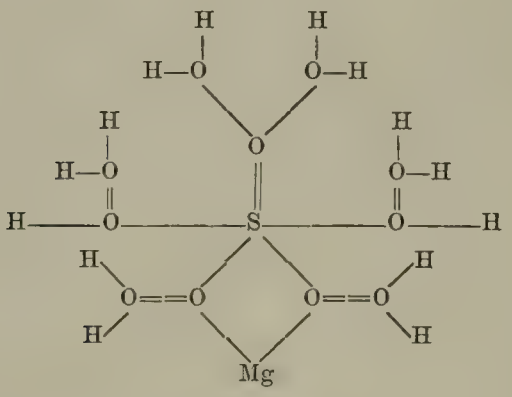
Another set of phenomena which the atomicity theory will not explain is the existence of well-defined crystalline salts containing what is called water of crystallisation. This water is in many cases held with considerable pertinacity, the body appearing to be a veritable chemical compound. But water appears to be a saturated body, the attractions of the oxygen being satisfied by those of the hydrogen. It is true that water acts vigorously on other compounds, as on metallic oxides to form hydrates, and on some anhydrides to form acids; but these appear to be phenomena of double decomposition; thus the combination of water with sodic oxide and nitric anhydride respectively may be expressed by the equations

$$OH_2 + ONa_2 = OHNa + ONaH \text{ and}$$
$$OH_2 + O(NO_2)_2 = OH(NO_2) + O(NO_2)H.$$

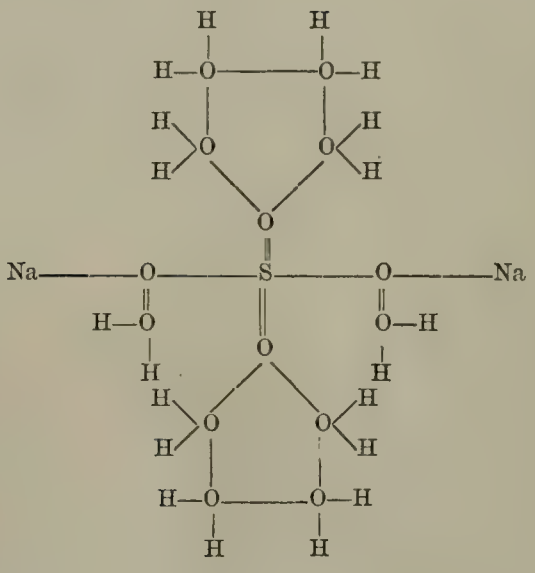
In the combination of water with an anhydrous salt, a phenomenon often accompanied by great rise of temperature, there does not appear to be a double decomposition. That there is a chemical combination of some sort is shown by the changes of properties produced, crystalline form and colour being both sometimes altered. Compounds so produced have been called 'molecular compounds' to imply that saturated molecules are in some way or another combined, the combination being different from 'atomic combination,' in which the atoms are directly united according to their valencies. Another explanation has been suggested by assuming that there is some 'residual affinity' not saturated by the constituents of the body, and that this residual affinity enables bodies to unite in a less stable manner than in most compounds. But are not these terms—'molecular combination' and 'residual affinity'—analogous to the term 'catalysis,' merely *words* to express—not to explain

—what we do not understand? If 'residual affinity' really exists, it must reside in the oxygen of the water, or in the hydrogen, or in both; if so, what will happen to some of the complex constitutional formulæ of the organic chemist in which the carbon is tetrad, the oxygen dyad, and the hydrogen monad? If any of these elements have a residual affinity should we not expect to find additional unions between some of the atoms of the same molecule over and above those represented by the formula?

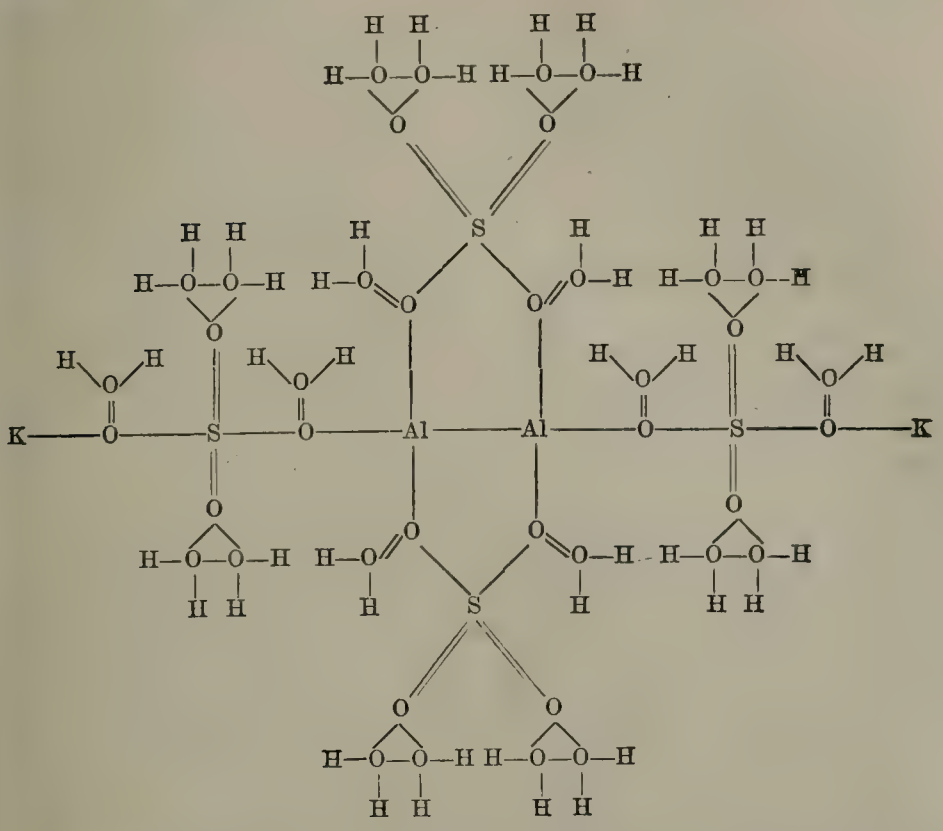
Oxygen may be tetrad, for which there is evidence in OAg_4. Under these circumstances water is by no means a saturated compound, and there would be no difficulty in explaining the combination of water with oxygen salts. Thus crystallised magnesic sulphate, $MgSO_4$, $7OH_2$ or $SOHo_2Mgo''$, $6OH_2$ would be—



and sodic sulphate, Na_2SO_4, $10OH_2$—



Even alum, with its twenty-four molecules of water of crystallisation, may be expressed by an appalling formula—



There is certainly a symmetry about the formula, and it will be found that sixteen of the molecules of water are in a different position from the remaining eight; this probably has no significance, although Graham found that crystallised alum at a temperature of 61° lost eighteen molecules of water; if he had used a temperature a few degrees lower he might have found that only sixteen passed off!

By a little stretching of the imagination and altering the atomicities of the elements to suit each particular case, no doubt graphic formulæ might be made for all crystalline salts, but they would be perfectly artificial, and not much good is likely to come from the attempt.

I fear we are driven to the conclusion that, notwithstanding all the progress that has been made in chemical science during the last fifty-eight years, we have not yet reached a method of notation that would have satisfied Dr. Dalton in 1834.

But since that time we have learnt that our formulæ ought to show even more than the number and position of the atoms of a compound; we should like them to indicate the amount of potential energy residing in a body, and our equations ought to indicate the amount of heat generated by a chemical change. Let us hope that before the next meeting of the British Association in Edinburgh these desirable developments will have been accomplished.

A short time ago I mentioned the word 'catalysis' as being employed to express certain chemical actions which cannot be explained. It is applied to those phenomena which take place in the presence of a body which appears to be entirely unchanged by the action. Happily these catalytic actions are being explained one after another, so that soon the name itself may become obsolete. An example of this action of presence may be given. When a mixture of sulphuric acid and alcohol is heated to a temperature of about 140° to 150° ether passes over. Now

alcohol contains C_2H_6O, and if from two molecules of alcohol one molecule of water is subtracted a molecule of ether results: $2C_2H_6O = OH_2 + C_4H_{10}O$. As sulphuric acid is known to have a great attraction for water, it is easy to imagine that the acid combines with the water and ether passes off. But it is found that a small quantity of sulphuric acid at the temperature of 140°–150° will transform a very large amount of alcohol into ether and water, much more than can be explained by assuming that the acid has combined with the water. If a mixture of sulphuric acid and alcohol is heated to a temperature of 140°–150°, and alcohol allowed to flow into the liquid, a mixture of ether and water vapours passes over, and after a large quantity of alcohol has been transformed the amount of sulphuric acid is found to be unaltered. At first glance this seems very difficult to explain, but on further investigation it is found that alcohol and sulphuric acid act one on another to form ethyl-sulphuric or sulphovinic acid—

$$SO_2Ho_2 + EtHo = SO_2HoEto + OH_2.$$

But when ethyl-sulphuric acid is heated with alcohol ether is formed with the reproduction of sulphuric acid—

$$SO_2HoEto + EtHo = OEt_2 + SO_2Ho_2.$$

The sulphuric acid is then able to produce ethyl-sulphuric acid by acting on more alcohol, so a continuous production of ether and water takes place without loss of sulphuric acid. Another well-known action is the combination of oxygen and hydrogen under the influence of spongy platinum. In this case the platinum remains apparently unaltered, and is capable of causing the combination of any quantity of mixed gases. As spongy platinum possesses the power of absorbing large quantities of gases it is usually said that the molecules of oxygen and hydrogen are so much condensed in the platinum that they are brought within the sphere of each other's attractions, and consequently combine.

Another instance of an action of this kind is afforded by the oxidation of ammonia in the presence of chromic oxide. When ammonic dichromate is heated an evolution of gas occurs, and a residue of chromic oxide is left which bears a striking resemblance to a mixture of black and green tea; when some of this substance is placed on a piece of wire gauze, heated and then supported over a vessel containing a strong solution of ammonia, the oxide glows, in a manner similar to the glowing of spongy platinum under the influence of a mixture of hydrogen and air. Under these conditions the chromic oxide facilitates the oxidation of the ammonia, but it becomes changed during the process; instead of having the appearance above described it acquires a bright-green colour. Now, we know that chromium is capable of forming several combinations with oxygen. Is it therefore too much to suppose that the chromium is alternately oxidised by the oxygen of the air, and reduced by the hydrogen of the ammonia, so that, although in the end it has the same composition as at the beginning, nevertheless it has been continuously decomposed and reproduced? Now, may not a similar change take place during the action of spongy platinum on a mixture of hydrogen and oxygen? The alteration of the platinum is very slight, but I believe I have observed a slight modification of the appearance of a fragment of spongy platinum that was kept glowing by a small jet of purified hydrogen for some hours; the gas not being allowed to burn so as to heat the platinum to a very high temperature, the metal appears to be compacted and to be covered by minute spherules of glistening metal. Now, may not the platinum have entered into combination with one or other of the gases and been subsequently reduced? If this is the true explanation then we have in this case a continuous series of chemical changes and the 'catalysis' is explained.

We all know the ease with which oxygen is obtained from potassic chlorate when heated with a small quantity of oxide of manganese: the quantity of peroxide is the same at the end of the process as at the beginning, and it may be used over and over again to assist in the decomposition of fresh potassic chlorate. The oxide

of manganese undergoes a molecular alteration; if a crystalline variety is employed, it is found, at the end of the process, to have been transformed into fine powder.

I hope I have proved to the satisfaction of my brother chemists that potassic permanganate is first formed and subsequently decomposed with the reproduction of manganese peroxide.

Oxide of cobalt possesses the remarkable property of decomposing solutions of hypochlorites at moderate temperatures with evolution of oxygen. For some time I have been endeavouring to find the explanation of the change, but hitherto without complete success. At first it seemed probable that an unstable cobaltate, analogous to a ferrate, was formed and decomposed at the temperature of the experiment. In fact, oxygen is evolved when chlorine is passed through a boiling solution of sodic hydrate containing ferric hydrate in suspension. But no evidence of the existence of a cobaltate could be found. When a cobaltous salt is added to an alkaline solution of a hypochlorite a black precipitate is formed which is usually stated to be cobaltic hydrate, Co_2IIo_6, but Vortmann has shown that, when a cobaltous salt is mixed with a solution of iodine in potassic iodide, and the liquid rendered alkaline by sodic hydrate, the precipitate formed at a temperature between 50° and 60° approaches in composition the dioxide of cobalt, CoO_2. He also found that the precipitate lost oxygen at the temperature of boiling water. I have repeated some of his experiments, and can quite confirm them, although I have not obtained an oxide containing quite as much oxygen as his richest oxide. The oxides I prepared rapidly effected the decomposition of a solution of sodic hypochlorite, and that without undergoing any loss of oxygen themselves; in fact, in the two experiments made the cobalt compound contained a little more oxygen after boiling with the hypochlorite.

We have now many instances of the influence which small quantities of substances have upon chemical reactions. These influences may be more common than is generally supposed. The presence of a third body is frequently helpful in the combination of elements with one another: thus dry chlorine will not attack melted sodium or finely divided copper; an electric spark will not cause a dry mixture of carbonic oxide and oxygen to explode; carbon, phosphorus, and sulphur will not unite with dry oxygen; and as chemical science progresses we may find that many well-known actions are conditioned by the presence of minute traces of other matter which have hitherto escaped detection. We all know the profound alterations of the properties of substances by minute traces of impurities; less than one-tenth per cent. of phosphorus will render steel unfit for certain purposes. The sapphire and ruby only differ from colourless alumina by the presence of traces of impurities hardly recognisable by chemical analysis. During this meeting we hope to have a contribution to the Section on the influence of minute traces of what may be called impurities on the properties of different substances and their influence on chemical changes.

In this city, where the first public chemical laboratory was started in 1823 by Dr. Anderson, the assistant of Professor Hope, it is hardly necessary to insist on the extreme importance of teaching chemistry by practical work, but unfortunately, even at the present time, endeavours are made to teach the subject by means of lectures (sometimes without experiments) or by reading. Those who are acquainted with chemistry well know the impossibility (this is hardly too strong a word) of learning the science, especially in the first stages, without actual experiment, by which a practical acquaintance with chemical phenomena is obtained. The attempt to learn chemistry without practical experience reminds one of the well-known story (for the truth of which I will not vouch) of a mathematician who lectured on natural philosophy. He was visiting a foreign laboratory, and stopped before a piece of apparatus and asked what it was: on being told it was an air-pump he exclaimed: 'Dear me! I have lectured on the air-pump for twenty-five years, and this is the first time I have seen one.' It is problematical if his students can have derived much advantage from his lectures. Teaching of the kind to which reference has just been made is generally given to candidates for examinations who do not intend to take up chemistry as their chief subject. At the present time chemistry is required for entrance and preliminary examinations

from many classes of students. There is no doubt that it is an excellent means of education, teaching a boy to observe and draw conclusions from his observations; but if he makes no observations it is little more than useless cram; the memory might as well be exercised by learning a novel by heart.

This imperfect mode of teaching chemistry arises principally from the difficulty of obtaining properly appointed laboratories in schools, in addition to which the very strong fumes are sometimes disagreeable, making it inconvenient to have them in or near a house, to say nothing of the possible dangers to the clothes and their contents; but there is no help for it; the teaching must be accompanied by experimental demonstration, as was indicated in the reports on the teaching of chemistry which have been presented to this Association in former years. It must be admitted that examinations do not always discover the best student; many are capable of preparing for examinations with a small knowledge of their subject; others, with a good knowledge, fail from nervousness or other causes; but at the present time examination, although far from perfect, is almost the only means we have of judging the fitness of the candidate. By properly selecting questions the examiner may, to a considerable extent, discourage cram; he should endeavour to find out what the pupils have actually seen, and to make them draw conclusions from facts which they have either themselves observed, or which have been described to them; it is only in this manner that chemistry can be used as a means of mental training.

These remarks do not apply to the education of students intending to make chemistry their profession, who have many opportunities, in the large laboratories of Great Britain and the Continent, of obtaining all the necessary instruction. The Institute of Chemistry, which was founded to improve the status and also the education of professional chemists, requires that its members should have a thoroughly scientific training. Before a candidate for the associateship is admitted to examination he must bring evidence that he has passed satisfactorily through a systematic course of at least three years' study in the subjects of theoretical and practical chemistry, physics, and elementary mathematics in some recognised college or school; and before admission to the fellowship he must have passed through three additional years of work in chemistry. It is to be hoped that an example of this kind will ultimately have a good effect in improving the modes of teaching the science in its elementary stages.

There is another class of workers in chemistry who must not be forgotten at the present time, as they have much influence on the life of the world, and have been working for ages, but have only recently been recognised. I mean those organisms which are included under the name of microbes. These organisms are capable of producing chemical changes which entirely surpass all the results hitherto obtained by the chemist in his laboratory. That the transformation of sugar into alcohol and carbonic anhydride in the ordinary process of fermentation is due to a living organism has been known for some years; the important transformation of ammonia into nitrous and nitric acids in the soil has been shown to be due to organisms which have recently been investigated by many chemists; it is possible to transform ammonia into these acids in the laboratory by oxidation under certain conditions and at a high temperature, whereas the organism does the work quite as efficaciously at the common temperature. Other organisms have the power of producing complex organic poisons by the alteration of some of the constituents of the animal body, and the relation of these products to the study of diseases is of the highest possible importance. As we hope to have a discussion on this interesting subject by many eminent authorities, both from the chemical and biological points of view, it will be unnecessary to pursue the subject further, unless it be to urge some of the younger chemists to work at the chemical aspect of bacteriology. They must be prepared for hard work and many disappointments, for the subject is undoubtedly a difficult one.

I cannot conclude this address without reference to the great loss which chemistry has sustained by the death of Professor A. W. von Hofmann. I had the good fortune to be under him as student and assistant from 1856 until he left this country in 1865; all who worked with him must have been deeply impressed

by his capacity for work and his power of inducing work in others. Although perhaps some of us did not appreciate this at the time, yet we feel we owe him a debt of gratitude for his having started us in the right way. The list of papers under his name in the Royal Society Catalogue up to the year 1883 is 299, written by himself alone, besides twenty-two joint papers. One of his characteristics which impressed me was his investigation for the purpose of furthering chemical knowledge without any view to practical applications, and I well remember his lecture at the Royal Institution, in 1862, on mauve and magenta (which owed so much of their success to his work), in which he produced the original specimen of benzene which had been obtained by Faraday from oil-gas in 1825. He pointed out that Faraday had prepared this substance and investigated its properties without ever supposing that it could have any practical application. The following is the concluding paragraph of the lecture:—

'Need I say any more? The moral of mauve and magenta is transparent enough; I read it in your eyes. We understand each other. Whenever in future one of your chemical friends, full of enthusiasm, exhibits and explains to you his newly discovered compounds, you will not cool his noble ardour by asking him that most terrible of all questions, "What is its use? Will your compound bleach or dye? Will it shave? May it be used as a substitute for leather?" Let him quietly go on with his work. The dye, the lather, the leather, will make their appearance in due time. Let him, I repeat it, perform his task. Let him indulge in the pursuit of truth—of truth pure and simple—of truth not for the sake of mauve, not for the sake of magenta; let him pursue truth for the sake of truth.'

This seems to me the true spirit of the scientific investigator, and in many cases the reward consists solely in the consciousness that the investigator has done his duty; in some cases the reward may take a more substantial form, and since the above paragraphs were written I have been informed that Professor von Hofmann has left a large fortune, the result of the applications of his discoveries in technical chemistry.

The following Papers and Reports were read:—

1. *Electrolytic Synthesis.* *By* Professor A. Crum Brown, *F.R.S.*, *F.R.S.E.*, *and* Dr. J. Walker.

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2. *Impurities in Chloroform.* *By* Professor W. Ramsay, *F.R.S.*

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3. *Report of the Committee on the Nature of Solution.*
See Reports, p. 261.

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4. *Report of the Committee on the Bibliography of Solution.*
See Reports, p. 261.

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5. *Report of the Committee on Wave-length Tables of the Spectra of the Elements.*—See Reports, p. 193.

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6. *A Note on Alloys of Aluminium with Ferro-manganese.*
By T. W. Hogg.

The alloys which form the subject of this short paper were prepared by mixing ferro-manganese with aluminium, both previously fused.

These alloys possessed the unexpected feature of being readily attracted by the magnet, and it is principally on this account that they have been thought sufficiently interesting to bring before the members of this section, especially as the alloys of aluminium have for some time attracted much attention.

It is now well known that the addition of manganese to iron or steel produces

an alloy which is not attracted by the magnet, alloys containing 8 to 12 per cent. being only feebly magnetic, and over this proportion they may be said to have practically no influence on the magnet at all.

Aluminium also possesses a similar property, but in a less marked degree. Ferro-aluminium containing 13 per cent. aluminium is still readily attracted, and it is not until this element reaches 20 per cent. that the effect here alluded to takes place.

It is therefore an interesting fact that the addition of aluminium to a manganese alloy, which of itself would be quite inert, results in an alloy which is readily attracted.

In one of the alloys exhibited the aluminium is present to the extent of 3·05 per cent. only, and although the iron barely reaches 15 per cent. it responds to the influence of the magnet almost as readily as a piece of iron.

In another alloy which was disintegrated the effect is still more remarkable, as it contains not only manganese but aluminium in sufficient quantity to destroy the influence of the magnet if they were present separately; yet together they do exactly the reverse, and here, again, although the iron is even less than the above, the magnet attracts it quite easily.

The alloys which I have drawn attention to were the result of an experiment made to ascertain the possibility of forming a reliable homogeneous alloy of aluminium with ferro-manganese, and for this purpose 50 lb. of the latter (containing 82 per cent. manganese) and 5·56 lb. of aluminium (containing 99·5 per cent. aluminium) were separately melted in large crucibles, the intention being to make a 10-per-cent. alloy. After they were perfectly fused the ferro-manganese was poured into the aluminium; after stirring for about half a minute the mixture showed such decided signs of becoming pasty that it was at once poured into an ingot mould. After about two-thirds had been poured the remainder suddenly solidified, and was roughly knocked out of the crucible.

The alloys presented no apparent dissimilarity, and it was not thought worth while to examine them until after keeping for about three months the portion which had solidified first commenced to fall into pieces—in the same way that high-percentage ferro-manganese of 85 per cent. is known to do—and this action has gone on until it has almost completely disintegrated, and is now in the condition of the specimen shown.

The analyses of the two portions showed a remarkable difference in composition. The disintegrated portion contains—

Iron	10·80
Manganese	54·86
Carbon	2·32
Aluminium	25·34
Silicon	0·79
Sulphur	traces
Phosphorus	0·107
Copper	0·075
	94·292

This analysis was repeated with practically identical results. The deficiency is no doubt due to slight oxidation having taken place owing to the finely divided condition of the alloy: it has a specific gravity of 3·61. The examination of the portion which was poured off showed it to have a specific gravity of 6·12, and that it contained—

Iron	14·80
Manganese	75·40
Carbon	5·55
Aluminium	3·05
Silicon	·886
Sulphur	trace
Phosphorus	0·184
Copper	·075
	99·945

This alloy has not shown any signs of disintegration since it was made.

Whether the difference in composition between the two portions is the result of the great difficulty in mixing aluminium with the heavier metals, or has been produced by separation, is not quite clear; if the carbon may be taken as a guide, it seems to show not only separation but also actual loss of this element.

FRIDAY, AUGUST 5.

The following Papers were read:—

1. *The Explosion of Ethylene with less than its own Volume of Oxygen.* *By* B. Lean, *B.A., B.Sc.* (*Dalton Chemical Scholar of Owens College*), *and* W. A. Bone, *B.Sc.* (*Fellow of Victoria University*).

Our investigations arose out of experiments to determine the rate of explosion of hydrocarbons with deficiency of oxygen, and were made at the suggestion of Professor H. B. Dixon. On exploding ethylene with less than its own volume of oxygen there is invariably a considerable increase in pressure. In the case of a mixture of 100 volumes ethylene with 96·5 volumes oxygen, the pressure increased from 756 mm. to 1,503 mm. of mercury, indicating that the oxygen had mainly gone to the carbon and not to the hydrogen. This result is in accordance with Dalton's experiments (1810), with those of J. Davy, Kersten (1861), and E. von Meyer (1874).

On carefully analysing the products of explosion we found that, in addition to hydrogen, carbon monoxide, and small percentages of carbonic acid and unsaturated hydrocarbons, there was always present a small amount of marsh gas.

We made and fired five different mixtures of ethylene and oxygen, containing 100 volumes ethylene with 70 to 96·5 volumes oxygen. We invariably found marsh gas present in the products of the explosion, and the percentage of this increased as the percentage of oxygen in the original mixture decreased.

The quantity of marsh gas present in the products of explosion of 100 volumes of ethylene with 70 volumes of oxygen was 5·53 per cent., and, in the case of the mixture containing 100 volumes ethylene with 96·5 volumes of oxygen, we found 1·01 per cent. of marsh gas in the products.

With regard to the unsaturated hydrocarbons present in the products, a qualitative examination revealed the presence of acetylene. Whether this constitutes the whole of the unsaturated hydrocarbons present we are not prepared to say; it is certainly present in not inconsiderable quantities.

The main reaction which doubtless occurs is a combination between the oxygen and part of the ethylene with the formation of carbon monoxide and hydrogen, according to the equation—

$$C_2H_4 + O_2 = 2CO + 2H_2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The heat liberated by this reaction produces a decomposition of some of the unburnt ethylene analogous to the decomposition which ethylene undergoes when passed through a red-hot tube into marsh gas and carbon, according to the equation—

$$C_2H_4 = CH_4 + C \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Marsh gas might also be produced in another way, by partial oxidation, according to the equation—

$$2C_2H_4 + O_2 = 2CH_4 + 2CO \quad . \quad . \quad . \quad . \quad . \quad (3)$$

With regard to the formation of acetylene, Professor Dixon suggested that it is possibly due to a secondary reaction between the nascent hydrogen formed according to equation (1), and the carbon liberated according to equation (2)—

$$2C + H_2 = C_2H_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

2. *On the Luminosity of Hydrocarbon Flames.* *By* VIVIAN B. LEWES, *Royal Naval College, Greenwich.*

In the year 1816, while engaged upon those historical researches which culminated in the discovery of the miner's safety-lamp, Sir Humphry Davy noticed certain facts which led him to work out and propound his theory of the causes which lead to luminosity in flame—a theory which is generally stated as being that the presence of solid particles in the flame is essential to its luminosity. This theory remained unquestioned until 1868, when Professor E. Frankland, in his celebrated communication to the Royal Society, showed that, although incandescent solid matter in a flame renders it luminous, luminosity is also in many cases produced when the flame contains very dense vapours at a sufficiently high temperature, and also that a non-luminous flame may be rendered luminous by increasing the pressure.

More recent researches, however, seem to point conclusively to the luminosity of all flames containing hydrocarbons, being due to the presence of incandescent particles of carbon, and the author has made an exhaustive series of experiments as to the causes which lead to their production in an ordinary coal-gas flame.

Coal gas is a mixture of hydrocarbons with hydrogen and small quantities of carbon monoxide; and it also contains traces of carbon dioxide, nitrogen, and oxygen.

The unsaturated hydrocarbons consist of ethylene, benzene, butylene, and acetylene, and probably also traces of crotonylene and others; while the saturated hydrocarbons consist chiefly of methane, with traces of ethane, propane, and butane.

As the gas leaves the jet the hydrogen rapidly diffuses to the outer edge of the flame and burns, the methane doing the same but rather more slowly. The combustion of these gases raises the temperature 500° C. in the first half-inch; while before another half-inch has been traversed 1,000° C. is reached, and chemical changes in the hydrocarbons are progressing rapidly, the unsaturated hydrocarbons and higher members of the saturated hydrocarbons being rapidly converted into acetylene. If the temperature of the flame were not allowed to rise above 1,000° C. this acetylene would be nearly all polymerised into benzene, naphthalene, diphenyl, and other more complex bodies, which would be slowly burnt up without liberation of carbon, and a non-luminous flame would result. This may be shown by holding a platinum dish against a luminous flat flame, when luminosity disappears; but it may be reproduced by heating the interior of the dish. In the case of a gas flame, however, instead of remaining at 1,000° C., the temperature rapidly rises to 1,200° C., with the result that, instead of polymerising into more complex bodies, the acetylene formed at once splits up into carbon and hydrogen, and the former, heated to incandescence by combustion, gives the luminosity. It is the attainment of this temperature that marks the limit of the non-luminous zone. If this were the only action, however, the luminous zone would be very short. But the bodies formed from the acetylene before 1,200° C. was reached, and the methane, of which some still remains unburnt, are converted into acetylene at a still higher temperature, *i.e.*, 1,300° C.; and this being reached near the top of the luminous zone yields a fresh supply of carbon, and so increases the height of the light-yielding portion of the flame.

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3. *Experiments on Flame.* *By* Professor ARTHUR SMITHELLS, *B.Sc.*

The author described four distinct regions of an ordinary luminous flame, the existence of which he thought could not be doubted by any impartial observer. His experiments had arisen from a desire to understand more fully the chemical changes which determined this peculiar structure, and especially the twofold character of the outer sheath.

He described the construction and demonstrated the use of his apparatus for separating the two cones of combustion in non-luminous flames, and gave a summary of the results he had obtained with it. He considered these results to furnish fresh proof that when a hydrocarbon is starved of oxygen, the carbon will

burn more readily than the hydrogen, and that accordingly the luminosity of ordinary flames must not be explained as is often done by assuming the very reverse of this. The luminosity of ordinary flames is now generally admitted to be due to the separation of solid carbon in the flame, and this must be ascribed to a decomposition or dissociation of the hydrocarbons by heat. This heat is supplied by the sheath of non-luminous combustion surrounding the flame. The author considers this sheath, which consists of two parts (a barely visible outer part, and a bright blue inner one) to correspond to the two cones of combustion in a non-luminous flame. The author, whilst admitting from the result of experiments made by Professor Lewes and by himself that acetylene was present in the interior of luminous flames, thought that Professor Lewes had not established his view that luminosity was mainly and essentially due to the formation and subsequent dissociation of acetylene, and that he was altogether relying too much upon that substance. A study of the precise cause of carbon separation was being undertaken by the author with the aid of his flame-cone separator, a single hydrocarbon (ethylene) being employed.

Other experiments with the flame-cone separator relating to the spectra of metallic salts were exhibited. An account of these will be found in the report of the proceedings of Section A, p. 645. The chief conclusion was that the spectra obtained when metallic salts were introduced into non-luminous flames were the direct outcome of and were entirely dependent upon chemical changes.

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4. *Report of the Committee on the Direct Formation of Haloids from Pure Materials.*—See Reports, p. 262.

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5. *The Reaction of Hydrogen with mixtures of Oxygen and Chlorine.* *By* J. A. Harker, *D.Sc.*

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6. *Preliminary Note on the Action of Dry Ammonia Gas on Sulphates.* *By* Professor W. R. Hodgkinson, *Ph.D.*, *F.R.S.E.*, *and* C. C. Trench, *Col. R.A.*

Very little appears in chemical literature as to the action of really dry ammonia gas on salts at an elevated temperature. Some chlorides are stated to be reduced, others to yield nitrogen compounds when heated with ammonia, but little or nothing seems to be known respecting the action with sulphates.

The experiments were also undertaken to ascertain (1) to what extent, if any, sulphates were reduced by ammonia at temperatures below that at which the sulphate itself decomposes, and (2) whether nitrogen compounds (nitrides) could be formed.

All the work has been quantitative as far as possible.

After a number of preliminary experiments, the reactions were carried on in a wide glass tube, so arranged that it could be heated in an air-bath to a definite temperature when required, or by the naked flame. The substance was contained in a boat of platinum or porcelain as the case demanded, which with its contents was weighed before and after the action. The ammonia was dried by passing first over potassium hydrate and then over a considerable quantity of freshly ignited lime.

As water is, however, certainly one product of the mutual action of ammonia and sulphates, this drying is perhaps not an essential precaution. To catch volatile products the tube was drawn out to about 50 cm., and either dipped into water or ended in a dry flask externally cooled.

General Results.—The preliminary experiments showed that some metallic sulphates were entirely reduced by heating with ammonia. Silver mercury and bismuth behaved in this manner. Water and what at first appeared to be

ammonium sulphite were the only products of a volatile nature. The actions were completed at the melting point of zinc.

Lead sulphate required a high temperature before any action was visible, and the salt was not completely decomposed by heating for an hour to a red heat. A little lead sulphide was produced. Thallium sulphate acted in a similar manner, but more sulphide was formed.

Ferrous sulphate (dry) precipitated by addition of strong acid to the concentrated water solution of $FeSO_4$ and then dried in vacuo, ordinary crystallised ferrous sulphate, and the ammonium ferrous sulphate were all reduced to metallic iron, which, however, contained 1 to 2 per cent. of sulphur.

The sulphates of zinc, manganese, cobalt, nickel, magnesium, and chromium were remarkably alike in their behaviour.

In all these cases the quantity of material left in the boat after heating corresponded very closely with that required if a sulphide of the form M^{S}_{2} had been formed. As a matter of fact, the residue consisted of a mixture of the sulphide and oxide in nearly molecular proportions.

No nitride has as yet been obtained.

As far as the volatile portion is concerned, the main bulk in all cases appeared to be ammonium sulphite. No trace of sulphate was found. In the hot tube in which the reaction was carried on, the substance which condensed was for the most part ammonium thionamate $NH_3OHSONH_2$. Where this came in contact with water in the condensing flask, or with moisture in the cooler parts of the tube, ammonium sulphite was of course formed.

Undoubtedly the most interesting salt examined is cupric sulphate. Either dry or with crystal water, the salt absorbed much NH_3, and then melted below 200° turned black, and as the temperature rose appeared to boil, and finally at somewhere about 400° began to decompose with incandescence, leaving almost pure metallic copper.

The comparatively low temperature at which an action was observable in the case of copper sulphate suggested the possible formation of a hydrazin compound.

The white sublimate was therefore examined for its reducing power on Fehling's solution and silver nitrate. As thionamate reduces both silver and copper solutions when alkaline, some of the white sublimate was distilled from potassium hydrate solution and the distillate collected in dilute sulphuric acid. This solution also reduced Fehling's solution. There is little doubt but that hydrazin is present along with the thionamate sublimate, but the quantity is small, and in several experiments could not be detected at all, probably on account of the temperature being too high when the ammonia comes in contact with the sulphate.

We are continuing this work in the hope of getting an easy method for the production of hydrazin compounds.

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7. *Note on the Action of Dry Sulphur Di-oxide on Oxy-salts.*

By Professor W. R. Hodgkinson, *Ph.D.*, *F.R.S.E.*, *and* J. Young, *A.R.S.M.*

The behaviour of sulphur di-oxide on solutions of certain oxy-salts, such as nitrates and chlorates, is sufficiently well known, and, in fact, a matter of every-day occurence. The reactions of the dry gas on these salts does not, however, appear to have been very carefully studied.

Some quantitative experiments have therefore been made with several typical salts. The mode of experiment has been to expose a weighed quantity of the salt to a current of carefully dried SO_2 in a tube so arranged that it could, if necessary, be heated to some definite temperature in an air-bath, or with the naked flame if desired.

Nitrates.—A considerable number of nitrates have been examined. As a rule, the action commences at the ordinary temperature coloured oxides of nitrogen are given off, and when the salt is employed in fine powder the temperature rapidly rises, and the metal in every case completely converted into sulphate. As long as the materials were quite dry no SO_3 was formed beyond that necessary to form sulphate with the metal.

Silver nitrate taken, 1·7068 grm.; sulphate found, 1·5660 grm.; calculated, 1·566 grm.

Potassium nitrate taken, 0·9490 grm.; sulphate found, 0·816 grm.; calculated, 0·8170 grm.

Chlorates.—The only salts of this class examined were those of barium and potassium. The first result of impact of the SO_2 was the liberation of chlorine peroxide, which escaped along with the excess of SO_2 as long as the temperature did not rise above about 60°; at a little higher temperature there was a slight flash in the tube and formation of white fumes of SO_3. The escaping gases then contained chlorine, SO_3 and SO_2. The yellow but clear mixture of sulphur di-oxide and chlorine peroxide became cloudy from formation of SO_3 on introduction of a little moisture.

Moist SO_2 appeared to act more rapidly than dry, and in most cases without visible liberation of chlorine peroxide.

Barium chlorate taken, 0·480 grm.; found as sulphate, 0·364 grm.; calculated, 0·367 grm.

Potassium chlorate taken, 1·0982 grm.; found as sulphate, 0·7798 grm.; calculated, 0·7797 grm.

Phosphates are apparently not acted upon at all by SO_2.

With chromates, dichromates, and permanganates considerable differences of behaviour were noticed, depending evidently on the nature of the metal. With silver chromate the figures point to the formation of silver sulphate and chromic oxide.

Silver chromate taken, 0·9348; after heating to near redness weight found was 1·0934; for a mixture of sulphate with chromic oxide it should be 1·092.

With alkaline chromates, or dichromate, or barium chromate there is an evident tendency to form chromium sulphate as well as other sulphate. In no case, however, has the formation of chromium sulphate proceeded its full extent even when the heating has been continued for many hours in a steady current of SO_2.

Permanganates behave in a similar manner.

With both classes of salts the action is at first rapid during the formation of the more positive metallic sulphate, and ceases at a higher temperature owing to the decomposition of the chromium and manganese sulphates by heat.

	Grm.
Potassium bichromate taken	1·6214
After heating in SO_2	2·0256
After reheating for two hours in SO_2 . . .	2·0468
Calculated as a mixture of Cr_2O_3 and K_2SO_4 it would be	1·7945
As a mixture of K_2SO_4 and $Cr_2(SO_4)_3$ . . .	3·1214

Potassium chromate taken	·907
After heating for half an hour in SO_2 . . .	1·1675
After reheating for two hours in SO_2 . . .	1·2606
Calculated as a mixture of K_2SO_4 and Cr_2O_3. .	1·1688

The ease with which potassium nitrate was converted into sulphate by the action of dry SO_2 suggested a method for the determination of potassium in gunpowder and similar substances. It was, however, found very unsuitable.

A number of experiments carried out by Lieutenant L. E. Traherne, R.N., show that when gunpowder is acted upon by SO_2 at about 150°, either dry or moist, the temperature rises quickly, and in most cases causes explosion. With fine-grained powders, and especially when unglazed, the action is more rapid and the explosion violent, as it appears to take place over a considerable area at once.

Chlorates, as might be expected, when simultaneously in contact with SO_2 and any kind of organic matter set up a violent action. A good form of lecture

experiment is to allow one or two drops of a solution of SO_2 in alcohol or ether to fall on a little powdered potassium chlorate; white fumes are given off which are nearly always followed by a sharp explosion.

SATURDAY, AUGUST 6.

The Section did not meet.

MONDAY, AUGUST 8.

The following Papers were read:—

1. *On the Application of a Hydrogen Flame in an Ordinary Safety-lamp to the Detection and Measurement of Inflammable Gas or Vapour.* *By* Professor Frank Clowes, *D.Sc., University College, Nottingham.*

The appearance of a 'cap' over the flame in the safety-lamp has long been used by the coal-miner for detecting 'firedamp' in the air, and for roughly measuring its amount. The ordinary oil-flame does not with certainty detect the presence of less than 3 per cent. of firedamp. The alcohol flame adopted by Pieler detects 0·25 per cent. readily; but since this flame gives no light the Pieler lamp can be used for gas-testing only, and is useless for lighting purposes. At the last meeting of the British Association the results of an examination of the Ashworth lamp were given by the author; this lamp burns benzoline, and was found to give good illumination when the wick was raised, and to detect at least 0·5 per cent of firedamp when the wick was pulled down until it gave a pale-blue flame only.

In the present paper the author describes a miner's safety-lamp, in which the ordinary flame can at once be replaced by a hydrogen flame when desired. The use of the hydrogen flame enables the miner to detect readily and with certainty percentages of firedamp, varying between 0·25 and 3·0, and to measure their amount. As soon as the delicate testing is finished the ordinary flame of the lamp is kindled, and can be employed either for illumination, or, if lowered, it can be applied to the detection of percentages of gas larger in amount than those found by the hydrogen flame. The hydrogen gas is carried in a small steel reservoir, slung over the shoulder by a strap, and is introduced through a fine metal tube which passes into the interior of the safety-lamp and terminates near the wick. This composite lamp is at once a good illuminator and an extremely delicate gas-tester.

Comparative experiments were made with a hydrogen flame, an alcohol flame of the same height, and a small blue benzoline flame, all of which were exposed in air containing 1 per cent. of coal gas. The 'cap' seen over the hydrogen flame was nearly four times as high as that seen over the benzoline flame, and half as high again as that seen over the alcohol flame.

Many serious accidents have arisen from bringing a 'naked flame' into spaces in which light petroleum oil had been stored. The vapour of this oil, when mingled with the air in proper proportions, is violently explosive; and it becomes important therefore to have means of detecting its presence and measuring its amount. The author described tests carried out with the above hydrogen safety-lamp in his test-chamber. They prove that the hydrogen flame can detect one-twentieth of the amount of petroleum vapour which can be kindled in air, and one thirty-sixth of the amount which explodes when mingled with air.

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2. *Report of the Committee on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases.*—See Reports, p. 263.

3. *Report of the Committee appointed to consider the best method of Establishing an International Standard for the Analysis of Iron and Steel.*—See Reports, p. 186.

4. *Notes on the Molecular Refraction and Dispersion of* (*a*) *Metallic Carbonyls,* (*b*) *Indium and Gallium,* (*c*) *Sulphur.* *By* Dr. J. H. Gladstone, *F.R.S.*

The author had examined a specimen of iron pentacarbonyl prepared by Ludwig Mond, which gave the molecular refraction of 67·33 for the line A, and 70·85 for the line E. It is therefore, like the nickel tetracarbonyl, a very refractive and extremely dispersive substance. He gave reasons for thinking that the metals in these two substances had not any abnormal valency, that the carbonyls have a ring formula, and that each CO in the iron compound has the high refraction of 11·2.

The refraction equivalents of indium and gallium had been previously determined from the observations of Soret upon alums of these metals. Soret, however, has since published additional observations, especially upon gallium alums. From these the atomic refraction of gallium was calculated at 11·6, and of indium at 13·7, which the author wished to substitute for his previous figures.

The refraction of sulphur had been determined by various observers in a solid, liquid, and gaseous condition, dissolved in carbon bisulphide, and in chemical combination with carbon and chlorine. These all gave nearly the same atomic refraction for the line D, viz., about 16·3; the sulphur dissolved in carbon bisulphide was the lowest, viz., 16·0, as determined both by Nasini and the author. The atomic dispersion of sulphur between A and G of the spectrum, whether dissolved in carbon bisulphide or in actual combination with the carbon, was the same, viz., 1·8. In more complicated organic compounds the atomic refraction and dispersion are generally smaller.

5. *The Effect of Small Quantities of Foreign Matter on the Properties of Metals.* *By* Professor W. C. Roberts-Austen, *F.R.S.*

6. *Researches on Diffusion.* *By* Dr. Svante Arrhenius.

7. *The Transpiration of Hydrogen through Palladium.* *By* Professor W. Ramsay, *F.R.S.*

TUESDAY, AUGUST 9.

The following Papers and Reports were read:—

1. *The Impurities of Town Air.* *By* G. H. Bailey, *D.Sc., Ph.D.*

During the past twelve months the Air Analysis Committee of Manchester, in conjunction with the Royal Horticultural Society, have been engaged on the analysis of the air of large towns. A large amount of information having been already collected by previous observers as to the carbonic acid in the air, it was

thought desirable to devote more special attention to such impurities as sulphurous acid and organic matter. Furthermore, since the object in view was not merely to collect data but to lay the foundations of what may be termed chemical meteorology, the atmospheric conditions prevailing at the time of the observation have been noted. From the results of several hundreds of analyses carefully conducted in London, Manchester, and Liverpool the following conclusions are drawn:—

(1) That in clear breezy weather the amount of sulphurous acid is less than 1 milligramme per 100 cubic feet of air.

(2) That in anticyclonic periods it rises very considerably, and in times of fog maxima of 34 and 50 milligrammes have been recorded for the worst districts of Manchester and London respectively.

(3) That wherever an open space or a less densely populated area occurs there is a very marked diminution in the amount of impurities in the air.

(4) That an increase in the amount of sulphurous acid is accompanied by at least as large an increase in the amount of organic impurities in the air.

(5) That smoke, promoting as it does the formation of fog, and preventing free diffusion into the upper stratum of the air, must be regarded as the principal cause of the impure state of the atmosphere in large towns.

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2. *Syntheses with the Aid of Butane and Pentane Tetra-carboxylic Ethers.* *By* Professor W. H. Perkin, jun., *F.R.S.*

3. *Synthesis of Hydrindon Derivatives.* *By* Dr. F. Stanley Kipping.

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4. *Heptamethylene Derivatives.* *By* Dr. F. Stanley Kipping.

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5. *Action of Phosphoric Anhydride on Fatty Acids.* *By* Dr. F. Stanley Kipping.

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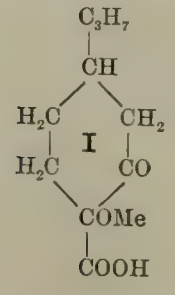
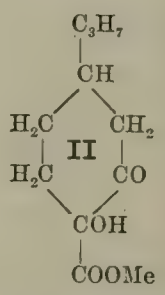
6. *Methyl Salts of Camphoric Acid.* *By* James Walker, *Ph.D., D.Sc.*

The author has prepared two isomeric methyl hydrogen camphorates, and investigated their electrolytic conductivity with a view of testing the validity of Friedel's formula for camphoric acid. The substances he obtained are identical with those recently prepared by Brühl. According to Friedel, camphoric acid forms two methyl hydrogen salts having the formulæ



and



Substances having these formulæ ought to be widely different in their strength as acids, and consequently in their dissociation constants as determined from the electrolytic conductivity of their solutions. I should have a constant greater than that of camphoric acid itself, while II should have a constant of at most one-tenth of that of camphoric acid. As a matter of fact, the constants of the two existing

isomeric substances are very nearly the same, and equal to about half the constant of camphoric acid, which is precisely what should be expected if camphoric acid were a dicarboxyl acid (compare Walker, 'Jour. Chem. Soc.,' 1892, p. 715).

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7. *The Halogen Addition Products of Salts of Organic Bases.* *By* Leonard Dobbin, *Ph.D.*, *and* James Walker, *D.Sc.*, *Ph.D.*

In 1885 and 1886 one of us in conjunction with Dr. Orme Masson [1] showed that the haloid salts of trimethylsulphine and of tetramethylammonium were acted upon by the halogens and by iodine monochloride with formation of compounds, the composition of which is represented by the general formula RX_3, where R stands for the group SMe_3 or NMe_4, and X for one atom of a halogen.

The products obtained in both cases differed very greatly in the readiness with which they underwent decomposition by themselves and on treatment with water or alcohol. The compounds containing three atoms of the same halogen were by far the most easily decomposed, and, indeed, the formation of *definite* compounds of this kind was never clearly proved, but only somewhat vaguely indicated. The only compounds which remained unchanged on exposure to the air, and which were further almost unattacked by boiling alcohol, were the dibromiodides prepared by the action of bromine upon the monoiodides. The corresponding dichloriodides, obtained from the monoiodides and chlorine, or from the monochlorides and iodine monochloride, decomposed slowly on exposure to the air, giving off chlorine and iodine. They were decomposed with moderate rapidity by boiling alcohol, with formation of the monochlorides of the organic bases, alcoholic solution of iodine, and products of the action of chlorine upon alcohol. Water attacked all the compounds, but while trimethylsulphine trichloride was instantly decomposed with liberation of torrents of chlorine, the dibrom- and dichloriodides of both bases were only decomposed after prolonged contact. The dichloriodides and dibromiodides were found to be very stable when heated, melting at temperatures ranging from 94° to 216°, some almost and others entirely without decomposition.

More recently the dibrom- and dichloriodides of methyl-pyridium have been prepared by us by the action of bromine and chlorine respectively on methylpyridium iodide. The dichloriodide has also been obtained by Ostermayer [2] from methylpyridium chloride and iodine monochloride. These substances both crystallise from alcohol, and were found to possess properties resembling in general those of the corresponding trimethylsulphine and tetramethylammonium compounds, being, however, more stable than these. The melting-point of the chlorine compound is 88°, that of the bromine compound being 63°.

In view of the serial character exhibited by these various substances with respect to their stability in alcoholic solution, it seemed to us that the determination of the molecular weights of the most stable of the compounds by observing with Beckmann's apparatus [3] the elevation of the boiling-point of alcohol in which they were dissolved might yield results of interest in regard to the so-called molecular compounds.

The results of the determinations showed that methylpyridium and tetramethylammonium dibromiodides are not decomposed to any appreciable extent by several minutes' boiling in alcoholic solution, while the trimethylsulphine analogue is undoubtedly attacked, and that the dichloriodides are all decomposed, some to a considerable degree, by the same treatment. The following table exhibits the molecular weights calculated from the formula RX_3 and from the elevation of the boiling-point respectively. Where there is no decomposition the values should be identical, and the more widely they diverge, the greater is the amount of decomposition.

[1] Dobbin and Masson, *Journ. Chem. Soc.*, **47**, 56 (1885), and **49**, 846 (1886).
[2] *Berichte*, **18**, 592.
[3] *Zeit. Physikal. Chem.*, **8**, 223 (1891).

	Dibromiodides		Dichloriodides	
	Theory	Found	Theory	Found
Methylpyridium	381	386	292	276
Tetramethylammonium . . .	361	353	272	239
Trimethylsulphine	358	293	269	208

These numbers were obtained immediately after the thermometer became steady. In the case of the dichloriodides the thermometer rose more or less rapidly as the ebullition was prolonged, and the molecular weight in consequence decreased, sinking to almost half the value indicated by the formula RX_3. That decomposition takes place in the case of the dichloriodides can also be seen from the change of colour in the solution, which, at first pale yellow, passes through deep yellow and orange to red.

These results tend to confirm our opinion that it is impossible to draw any sharp distinction between 'atomic compounds' of great stability under conditions of very varied character and 'molecular compounds,' which are unstable under the same conditions. For the perfectly stable methylpyridium dibromiodide and the unstable trimethylsulphine trichloride, which can only exist in an atmosphere of dry chlorine, are perfectly analogous compounds, and are merely the end terms of a series, the intermediate terms of which have intermediate degrees of stability.

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8. *The Production of Acetic Acid from the Carbohydrates.*

By J. F. V. Isaac, *B.A.*

The purpose of this research is to give a quantitative account of the decomposition of the carbohydrates by 'fusion' with alkaline hydrates, regulating the conditions of the decomposition so as to give the maximum production of acetic acid. To determine this maximum and the conditions under which it is attained, the several factors have been varied, and the effects of the variations ascertained. Thus temperature, time, nature of alkaline hydrate (NaOH, KOH, &c.), and proportions of the alkali to carbohydrate have been investigated; and further various carbohydrates of typical constitutions have been studied, chiefly cane sugar, cellulose (cotton, flax, and other forms), hydracellulose (product of action of concentrated hydrochloric acid on cotton cellulose), jute, and pine wood. The following are the more important results:—

Temperature.—The formation of acetic acid is observable at 100–110° C.; it becomes considerable at 150° C., and reaches a maximum at 250–350° C.

Time.—The duration of the heating is, as might be expected, of considerable influence at the lower temperatures; at higher temperatures the decompositions are rapidly completed.

As regards the alkali and the proportion of alkali to carbohydrate, the maximum yields are obtained with potassium hydrate, and in the proportion of three parts to one of carbohydrate.

The various carbohydrates above named appear to yield approximately the same maximum of acetic acid, viz., from 30–40 per cent. of their weight under the most favourable conditions. The addition of weak oxidising agents, *e.g.*, ferric hydrate and potassium ferricyanide, tends to increase the yield of acetic acid, more especially at the lower temperatures.

The other products of the decomposition are oxalic and carbonic acids, together with gaseous compounds continuously evolved. In addition to hydrogen, which is the chief constituent, a small quantity of a gaseous carbon compound is formed, presumably CH_4 or CO. On passing the gases evolved from the decomposition of sugar with potassium hydrate over red-hot copper oxide in a combustion tube the atomic ratio of the H to C determined was found to be in two experiments 29 : 1 and 20 : 1 respectively. The hydrogen evolved was found to be from 40–50 per cent. of that contained in the original substance.

The products of resolution of cane sugar under these conditions are therefore approximately per two molecules of the compound ($C_{12}H_{22}O_{11}$): acetic acid, 4 molecules; oxalic acid, 1 molecule; carbonic acid, 13 molecules; gaseous carbon compound, 1 molecule; hydrogen, $10H_2$. The other carbohydrates will be similarly investigated.

While reserving a complete account of the research until further advanced, it is sufficiently established that all the carbohydrates investigated break down similarly, that acetic acid is the main product of the resolution, and that the $CO-CH_2$ grouping is an important factor of the stability of the molecules of these compounds, and survives this very drastic process of resolution.

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9. *On the Molecular Volumes of Organic Substances in Dilute Solution.* *By* W. W. J. Nicol, *D.Sc.*

In 1883 the author found that when dilute solutions of the sodium salts of formic, acetic, and butyric acids were compared the differences between their molecular volumes were approximately constant per CH_2. Thus:—

			CH_2
Sodium butyrate	67·46	27·4	13·7
„ acetate	40·05	14·9	14·9
„ formiate	25·19		

The sodium butyrate was not quite pure, containing acetate, so that the probable volume of CH_2 in aqueous solution was 15.

During the past year the author has returned to this point, and it is his intention to fully examine a series of organic bodies in various solvents with the object of ascertaining the apparent volumes of C, H, O, &c., in organic bodies. The work is at present only in the preliminary stage, but the results are such as to encourage him to proceed with it.

Solutions of the commoner compound ethers in benzol, xylol, and rectified spirits have been prepared and their densities determined. The solutions were made by dissolving weighed quantities of the ethers in known amounts of the solvents, and the densities were determined at 20° C.

—	Xylol	Benzol	R.S.
Ethyl formate	81·1	81·9	81·1
Butyl acetate	132·4	133·9	134·3
Amyl formate	131·5	133·4	133·3
Ethyl valerate	148·2	150·1	150·6
Amyl acetate	148·2	150·4	150·6

Grouping these we have:—

$C_3H_6O_2$	81·1	81·9	81·1
$C_6H_{12}O_2$	132·0	133·7	133·8
$C_7H_{14}O_2$	148·2	150·2	150·6

From this as an approximation we have:—

—	Xylol	Benzol	R.S.
$3(CH_2)$ =	16·9	17·3	17·6
CH_2 =	16·2	16·5	16·8

Further,

Amyl benzoate in benzol	= 191·9
Ethyl „ „	= 142·4
$3(CH_2)$	= 49·5
or CH_2 in benzol here	= 16·5

With regard to these results it is to be noted that the ethers were obtained from commercial samples by fractionation, and the composition has not yet been checked by analysis or by determining the vapour density; further, that, while in the first series the value of CH_2 depends on two substances for each of the members of the pair, that of $3(CH_2)$ depends on one substance for one of the pair and two for the other, and it is most probable that the ethyl formate is slightly acid, and thus the molecular volume is too low, and the value of CH_2 is too high.

We may also notice that, comparing the molecular volumes of each substance in the three solvents, or their differences per CH_2, and including water—

——	Water	Xylol	Benzol	R.S.
CH_2 =	15·0	16·2	16·5	16·8

10. *Report of the Committee on Isomeric Naphthalene Derivatives.*
See Reports, p. 191.

11. *Report of the Committee on the Action of Light on Dyed Colours.*
See Reports, p. 263.

12. *On the Amount of Hydrolysis in Aqueous Solutions of Salts of Strong Bases with Weak Acids. By* Dr. J. Shields.

The author has calculated the amount of free alkali in several salts from observations of the velocity of reaction on saponifying ethyl acetate by their solutions, and finds that it is very nearly proportional to the square root of the concentration of the salts.

The actual quantity contained in $\frac{1}{10}$ molecular normal solutions of the following salts at 24°·2 C. is—

Potassium cyanide		1·12 per cent.
Potassium phenate		3·05 „
Sodium carbonate		3·17 „
Borax	(about)	0·5 „
Sodium acetate		0·008 „

Tri-sodium phosphate in $\frac{1}{50}$ molecular normal solution was found to be almost completely hydrolysed into di-sodium hydrogen phosphate and sodium hydrate.

13. *A new Method for Measuring the Pressure produced in Gaseous Explosions. By* Bevan Lean, *B.A., B.Sc., Dalton Chemical Scholar of the Owens College, and* W. A. Bone, *B.Sc., Fellow of Victoria University.*

The authors have devised a new method by which they hope to be able to measure the pressure produced on the explosion of gaseous mixtures. All former measurements involve the motion of a gauge of considerable mass. Bunsen measured the pressure developed by studying the limiting weight raised by a valve attached to a bomb. Berthelot and Vieille determined the rate of displacement of a piston of known section and mass. Mallard and Le Chatelier have employed a Deprez manometer, and also a metallic Bourdon gauge. Dugald Clerk has made use of a Richards indicator. In consequence of the instantaneous character of gaseous explosions it is doubtful whether, by the means employed by these experimenters, it is possible to measure the *real* pressure produced by the explosion. Their methods would appear to measure no more than the effective pressure.

The authors give preliminary experiments in which they have studied the pressure produced by the explosion of a mixture of two volumes of hydrogen with one volume of oxygen.

They attached to a leaden coil of two litres capacity a strong glass tube of 10 to 25 cubic centimetres capacity, closed at one end, and separated at its other end from the coil by a gas-tight steel tap, the bore of which had the same diameter as the glass tube. The glass gauge had previously been calibrated and graduated. The coil was then filled with the explosive mixture, while the glass gauge together with the bore of the tap was filled with air or hydrogen. The instant before the mixture was fired the tap separating the coil from the gauge was opened, and the flash due to the exploding gases darted into the gauge. The experiment consisted in taking a photograph upon a sensitive plate of the flash in the gauge. It was found possible to obtain photographs which showed the flash to come to a well-defined and abrupt termination, marking the volume into which the air in the gauge had been compressed. By this means the authors hold that the air in the gauge is compressed adiabatically, and with the data afforded by the photograph they had originally intended to calculate the pressure produced in the explosion by Rankine's well-known formula

$$P' = P \cdot \left(\frac{V}{V'}\right)^{\kappa}.$$

The assumption was therefore made that there is no loss of heat up to the time that the flash attains its furthest limit. To obtain some data to justify this assumption the authors took a photograph of the flash upon a swinging plate attached to a pendulum chronograph. The plate moved past the flash at the rate of $2\frac{1}{2}$ metres per second. The photographs so obtained could scarcely be distinguished from those taken upon a stationary plate; they were perfectly symmetrical; only the slightest possible increase in breadth could be detected. These photographs showed that the compression is approximately instantaneous, and that the flash ceases to have any sensible photo-chemical action in an interval of time less than one five-thousandth of a second. In so short an interval of time the compressed gas cannot lose a sensible quantity of heat. It would appear, therefore, right to assume that the compression is adiabatic. The authors believe also that no appreciable diffusion of the compressed gas into the compressing gas can occur during the very brief time of compression.

Further, since thermo-dynamic theory proves the ratio of the two specific heats of any perfect gas to be approximately constant for all temperatures and pressures, Rankine's formula may be employed to calculate the pressure produced by the explosion when the gauge is filled with air or hydrogen.

Essentially, therefore, the method gives a record of the adiabatic compression of a gas by the explosion, a piston of indefinitely small thickness and mass being interposed between the compressed and compressing gases.

Experiments have been made with gauges of different volume, varying from 11·55 cubic centimetres to 23·20 cubic centimetres, and the ratio $\frac{V}{V'}$ is found to be independent within these limits of the volume of the gauge. Further, the ratio $\frac{V}{V'}$ is found to be the same, within the error of experiment, whether air or hydrogen is the gas compressed. The photographs obtained, however, in the case of hydrogen show the flash to be in general ill-defined and pointed, owing probably to the high thermal conductivity of hydrogen, combined with a much greater inter-diffusion with the compressing gases in consequence of the greater molecular velocity of hydrogen in comparison with that of air.

The mean value from six different sets of experiments with air and hydrogen, electrolytic gas being the explosive mixture, gave $\frac{V}{V'} = 8{\cdot}6$. Calculating P' by means of Rankine's formula, and taking $\kappa = 1{\cdot}408$, it is found that $P' = 20{\cdot}7$ atmospheres. This pressure is about twice that measured by former experimenters. Some experiments were also made with carbonic acid gas; in these the explosion compressed the gas into a much smaller volume, owing to the great variation of the two specific heats of carbonic acid gas with increase of temperature and pressure.

A careful consideration, however, of these experiments makes it very doubtful whether the pressure can be calculated in this way. It would appear that the problem cannot be treated as other than a hydrodynamical one, the solution of which must be left to the mathematician. There can be little doubt that the inertia of the gases cannot be neglected, and that the pressure produced by the explosion is less than that calculated above, namely, 20·7 atmospheres.

The authors desire to state that the idea upon which their method is based was suggested to them by Professor H. B. Dixon.

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14. *The Determination of small Quantities of Nitrogen in Soils.* *By* Dr. F. E. Matthews.

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15. *On a Vanadiferous Lignite found in the Argentine Republic, with Analysis of the Ash.* *By* John J. J. Kyle, *Sc.D., Professor of Chemistry in the University of Buenos Ayres, Assayer to the Argentine Mint.*

By order of the Minister of the Interior of the Argentine Republic the Director of the National Board of Works forwarded to the author a small sample of coal, taken from a seam recently discovered near the town of San Raphael, in the province of Mendoza, with instructions to analyse the mineral and to report on its value as a combustible. The coal is lustrous, black even when finely pulverised, without fibrous structure, and remarkably brittle. On being heated it softens, emits much gas, which burns with a smoky flame, yielding a light spongy coke, which after combustion leaves a singularly small amount of a greenish coloured ash. The condensed products of its distillation have an acid reaction.

The specific gravity of the mineral is 1·173.

Its proximate analysis gave—

Loss on drying at 100° C.	2·05
Volatile matters	49·51
Fixed carbon	47·81
Ash	0·63
	100·00

Its elementary composition, deducting hydroscopic water and ash, was found to be as follows :—

Carbon	60·59
Hydrogen	8·63
Nitrogen	1·43
Sulphur	4·23
Oxygen	25·12
	100·00

The composition of the ash, after deduction of the carbon (which two separate determinations had shown to amount to 27·8 per cent. in the ash as analysed) may be stated as follows :—

Soluble in acid	Vanadium pentoxide	38·22
	Phosphorus pentoxide	0·71
	Sulphuric anhydride	12·06
	Calcium oxide	8·44
	Ferric oxide	4·98
	Aluminium oxide	3·32
	Potassium oxide	1·73
Insoluble in acid	Silicic anhydride	13·70
	Ferric oxide	9·42
	Aluminium oxide	5·26
	Magnesium oxide	0·83
	Undetermined traces of manganese, magnesium, chlorine, and loss in analysis	1·33
		100·00

From the foregoing it is evident that the San Raphael coal is one of great interest, being not only of fair quality as a combustible, but being also available as a source of vanadic acid for industrial purposes, seing that each ton of the mineral, supposing it to be equal to the sample, will produce over 14 lbs. of *pure* ash containing $4\frac{1}{4}$ lbs. of the vanadic pentoxide, of which $3\frac{1}{2}$ lbs. may be extracted by simple treatment of the ash with an alkaline liquor, whilst the remainder is of course susceptible of extraction from the insoluble part, as in the case of basic slags of Creusot ('Comptes Rend.,' xcv. 42–44), which contain but 1·5 per cent. In short, the ash of the San Raphael lignite is, so far as my knowledge goes, the richest known material utilisable as a source of vanadium compounds. I have taken steps to obtain information regarding the carboniferous strata whence my sample of mineral was derived; the details cannot fail to be of great interest. Meanwhile I have been assured that the seam where explored is about a metre in thickness. The Argentine provinces of Cordoba and San Luis are already well known as sources of vanadium minerals, such as vanadinite, dixloizite, and psitlacinite. The province of Mendoza must now be added to the list of localities in the Argentine Republic where vanadium is to be found.

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16. *Sewage Precipitation.* *By* G. Carrington Purvis.

WEDNESDAY, AUGUST 10.

The following Papers and Reports were read:—

1. *Atomic Weight of Boron.* *By* W. Ramsay, *Ph.D., F.R.S., and* Emily Aston, *B.Sc. (Lond.)*

We have made a re-determination of the atomic weight of boron by the following methods:—

1. A preliminary re-determination of the water of crystallisation in borax.

2. Conversion of anhydrous sodium borate into sodium chloride, by distillation of the borax with hydrochloric acid and methyl alcohol, and weighing the resulting sodium chloride.

Pure borax was prepared from pure boracic acid and pure soda. It was found to be an efflorescent substance, so the estimation of the water of crystallisation is hardly a method suited for an atomic weight determination. We made our experiments upon it during damp weather, so that the loss of water that it underwent was not great.

Method I.

Determination of the water of crystallisation in borax, $Na_2B_4O_7.10H_2O$.

A weighed quantity of borax, generally about 5 grams, was placed in a platinum dish, and heated in an air-bath at a temperature of about 90–110° C. for some time; the temperature was gradually raised to about 350° C.; the borax swelled up very much, and in some cases there was loss by spurting; the dish was then taken out of the air-bath, and the borax fused over the blowpipe; it was then allowed to cool in a desiccator, and the fused borax weighed. The loss in weight gave the percentage of water, from which the atomic weight was calculated.

The results are given in Table I. The mean atomic weight obtained is 10·921 for boron.

The atomic weights used in the calculations are: H = 1·008; O = 16; Na = 23·05; Cl = 35·45; Ag = 107·92.

TABLE I.

Expt. No.	Weight of crystalline borax	Weight of fused borax	Percentage of water lost	Atomic weight of boron
3	10·3581602	5·4784357	47·1099	11·04
5	5·3440089	2·8246677	47·1433	10·97
6	4·9962580	2·6378934	47·2026	10·85
7	5·7000256	3·0101127	47·1912	10·87
9	5·3142725	2·8065646	47·1882	10·88
11	4·9971924	2·6392016	47·1865	10·885
12	5·2366921	2·7674672	47·1524	10·955
Aggregate	41·9466088	22·1631808	47·1633	10·93

Mean atomic weight B = 10·921.
Probable error ± ·010.

METHOD II.

Distillation with methyl alcohol and hydrochloric acid.

A weighed quantity of anhydrous borax was dissolved in a small quantity of water, alcohol added, and an excess of pure hydrochloric acid; it was then distilled on a water-bath with addition of methyl alcohol, till boracic acid could no longer be detected in the distillate by the flame test. The flask was then dried in an air-bath at a temperature of about 100–110° C. in a slow current of air. The temperature was then raised to about 350° for two or three hours to drive off the last traces of water; the flask was then left to cool, and weighed after it had stood for some time in the balance case.

The weight of salt obtained from the borax was thus determined; the sodium present was calculated; from this number the amount of borax corresponding to two atomic proportions of sodium was found; this number less Na_2O_7 gave B_1, and hence the atomic weight of boron.

In the first series of experiments a flask of soft glass was used. The results obtained were not very concordant, for the glass was attacked, replacement of oxygen by chlorine took place, resulting in the formation of silica and sodium chloride from sodium silicate, for on dissolving the salt in water an insoluble residue of silica was left.

The results are given in Table II.; the mean atomic weight is 10·952, and is not far from that obtained in the next series of distillations.

TABLE II.

Expt. No.	Weight of fused borax	Weight of sodium chloride	Atomic weight of boron
14	4·7684431	2·7597665	11·015
15	5·2740318	3·0578213	10·925
16	3·2344088	1·8727203	10·992
17	4·0861923	2·3713122	10·879
18	3·4970297	2·0265645	10·949
Aggregate	20·8601057	12·0881848	10·951

Mean atomic weight B = 10·952.
Probable error ± ·010.

SECOND SERIES.

To avoid the error introduced by the action of the hydrochloric acid and alcohol upon the soft glass, a flask made of combustion tubing was used. It was found that this glass was hardly acted upon, but when the salt was dissolved in water a very slight residue of silica was left. In order to check the results, the chlorine in the sodium chloride was estimated with silver nitrate in the usual manner; the

silver chloride was collected on a Gooch's filter, and dried in an air-bath at a temperature of about 200° C. The results obtained gave a rather low percentage of chlorine; calculated with Clarke's atomic weights it is 60·598. If the atomic weight of boron is determined from the chlorine, it is rather higher than that given from the weight of salt.

TABLE III.

Expt. No.	Weight of fused borax $Na_2B_4O_7$	Weight of sodium chloride NaCl	Atomic weight of boron	Weight of silver chloride AgCl	Chlorine per cent. in sodium chloride	Atomic weight of boron from chlorine
22	5·3118075	3·0761181	10·983	7·525869	60·493	11·071
23	4·7805583	2·7700458	10·955	6·7794186	60·515	11·024
24	4·9907395	2·8929844	10·936	7·0804317	60·516	11·003
25	4·7231225	2·7360411	10·968	6·6960242	60·514	11·039
26	3·3137921	1·9187258	10·992	4·6931271	60·479	11·091
Aggregate	23·1200199	13·3939152	10·965	32·7748706	60·505	11·084
	Mean atomic weight of boron 10·966. Probable error ± ·005.				Mean atomic weight of boron 11·052. Probable error ± ·010.	

Since no special precautions were taken to obtain pure silver for the chlorine determinations, but ordinary silver nitrate was employed, it is probable that the distillation results yield the more correct atomic weight of boron, which is therefore 10·966.

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2. *On the Preparation of pure Glucina, and the Atomic Weight of Glucinum.* *By* Dr. J. GIBSON.

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3. *On the Assumed Potential Difference between a Metal in the Molten and the Solid State.* *By* Professor W. OSTWALD.

If two pieces of the same metal are immersed in a suitable electrolyte containing this metal as an ion, and the whole is maintained at the melting-point of the metal, it is possible to keep one of the pieces in the solid, the other in the liquid state. It is generally admitted that such a system would show an electromotive force, the amount of which can be calculated from the latent heat of the fused metal.

But if there were indeed a potential difference between both the electrodes, it would be possible to gain electric energy, and therefore also mechanical work, from heat *at a constant temperature*, contrary to the second law of thermodynamics. A potential difference is therefore impossible in this case.

To control this conclusion several experiments were executed at my request by Dr. Lash Miller in my laboratory. They led to the result that no potential difference exists between the same metal in the solid and in the liquid state at the melting-point. The cells consisted of tin in a molten mixture of sodium and potassium nitrates, of lead in molten zinc chloride containing some lead chloride, and of mercury in sulphuric acid of 60 per cent., and mixed with mercurous sulphate. In no case was it possible to detect a potential difference of 0·001 volt. The above-mentioned calculation from the latent heat would give some centivolts.

It is easy to deduce from the second law of thermodynamics that at the melting-point there must be a break in the E.M.F., although not a jump. The case is fully analogous to the case of vapour pressure upon water and ice. Indications of the break were observed, but no measurements were made.

If the metal is combined with another, forming a cell of the Daniell pattern, and the chemical energy of the combination is converted by the current generated

in this cell fully into electrical energy, the metal being solid, there must be a difference of both the energies if the same metal is in the liquid state, and *vice versâ*. It is therefore proved that there must exist cells whose chemical and electrical energies are not equal.

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4. *Note on Exact Weighing.* *By* Dr. J. Gibson.

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5. *Analysis of Manganese Nodules.* *By* Dr. J. Gibson.

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6. *On the Iodides of Sulphur.*
By Professor Herbert McLeod, *F.R.S.*

An iodide of sulphur, SI_6, isomorphous with iodine was prepared by Landolt and measured crystallographically by vom Rath (Pogg. 'Annalen,' cx. 116). It was made by allowing a solution of iodine and sulphur in carbonic disulphide to evaporate spontaneously. As the existence of this compound has been adduced as a proof of the hexad character of sulphur, it seemed advisable to investigate its properties.

Some of the substance was prepared by the process mentioned, and in order to separate it from any admixture of iodine it was placed in a tube which was afterwards exhausted by the Sprengel pump and sealed. One end of the tube was then surrounded by muslin, kept wet with water by means of a piece of cotton-wick; iodine volatilised, at first rapidly, but afterwards more slowly. After the lapse of three months a residue was left at the end of the tube, which, on analysis, was found to contain 98·5 per cent. of sulphur.

Another quantity was dissolved in carbonic disulphide and the solution allowed to evaporate; as crystals were formed the liquid was poured off and the crystals washed with carbonic disulphide. In this manner five crops of crystals were obtained, none of which contained more than ·5 per cent. of sulphur; the residue left on allowing the mother liquor to evaporate contained 56 per cent. of sulphur.

The iodine is entirely removed from the substance by digesting it in a solution of potassic iodide.

When some of the powdered substance is exposed to the air in a shallow layer the iodine all volatilises, leaving a residue of sulphur.

When acted on by a solution of sodic hydrate a residue of sulphur is left, and the solution gives very little precipitate with baric chloride after acidifying with hydrochloric acid.

The properties of the substance seem to indicate that it is a mechanical mixture of iodine and sulphur, and not a chemical compound.

Some experiments were then made with the iodide of sulphur, S_2I_2, described by Guthrie. This was prepared by mixing chloride of sulphur, S_2Cl_2, with ethylic iodide and allowing the mixture to remain in a sealed tube for four days. Black crystals were then found in the tube. On opening the latter a large quantity of the vapour of ethylic iodide escaped. The crystals were removed from the tube and powdered. On heating a portion in a test tube it fused at a temperature a little above the boiling point of water.

Some of the substance in vacuo gave off iodine, leaving a light-coloured residue.

Some of the substance dissolved in sulphide of carbon was crystallised fractionally: the first crop contained ·38 per cent. of sulphur; the second, ·31; the third, 1·07; and the fourth, 34·78. On allowing the mother liquor to evaporate the residue contained 76·32 per cent. of sulphur.

When acted on by sodic hydrate the iodine is removed and all the sulphur remains behind, the solution giving no precipitate with baric chloride after adding hydrochloric acid. It is usually stated in text-books that the compound undergoes a decomposition similar to that of chloride of sulphur, forming an iodide and a sulphite or thiosulphate with separation of sulphur.

The fusing point being lower than those of iodine and sulphur would indicate that some chemical action takes place when the elements are mixed together, but its properties more resemble those of a non-metallic alloy than of a definite chemical compound.

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7. *On Solutions of Iodine.* *By* W. W. J. Nicol, *D.Sc.*

The question as to the composition of the iodine molecule in solution is one which has from time to time attracted the attention of chemists. It is well known that the colour of dilute solutions of iodine is dependent largely on the nature of the solvent, and this difference of colour has been generally attributed to a greater or less complexity of the iodine molecule. The well-known violet of iodine vapour is characteristic of the solution of iodine in carbon disulphide, and from this it is argued the molecule must be the same in both states, *i.e.*, I_2.

The methods employed for the determination of the molecular weight of iodine in solution have been two: that dependent on the lowering of the freezing point of the solvent—a method necessarily applicable to but few solutions—the other relies on the alteration of the vapour pressure of the solvent, a method of general applicability. The first of these has been employed by Gautier and Charpy, the second by Loeb and Beckmann.

But these results are far from satisfactory, and the author has endeavoured to throw further light on this subject by a study of the molecular volume of iodine in solution. His experiments are far from complete, but he wished to lay some of the first results before the Section with the object of reserving his special method of investigating the point.

The method of experimenting is extremely simple: solutions of iodine in various solvents are prepared of definite strength by direct weighing of both substances, the specific gravity of the solutions is then determined at a definite temperature (20° C.), and thus the apparent volume of the iodine in solution can be calculated.

The following are the results obtained:—

Solvent	Atomic Volume I.	
Ether	21·2	
Rectified spirits	31·3	
Benzol	31·1–31·3	(3–9 per cent. I.)
Chloroform	32·4	
Carbon disulphide	35·6	
Potassium iodide, 13 per cent.	21·8	(3 „ „)
„ 8 „	28·7	(1 „ „)
„ 4 „	29·4	(1 „ „)

Neglecting the three results with potassium iodide for the present we find on dividing the atomic weight by the atomic volume that the densities of iodine in the first five solvents are as follows:—

		Atomic Volume calculated
Ether	= 6·0	$\frac{127}{6} = 21·1$
Rectified spirits	= 5·0	$\frac{127}{4} = 31·7$
Benzol	= 5·0	— —
Chloroform	=	
Carbon disulphide	= 3·5	$\frac{127}{3·5} = 36·3$

While solid iodine has a density of 5·0 and the atomic volume 25·4.

The solutions in solutions of potassium iodide clearly belong to a different order; there is evidently combination more or less complete between the potassium iodide and the iodine.

Before any definite conclusion can be arrived at the experiments must be extended to include other solvents, and the behaviour of all the solvents with some substance which does not alter its molecular constitution must be fully examined. This the author intends to carry out at once.

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8. *Persulphates.* *By* Dr. H. MARSHALL.

9. *Cobaltic Salts.* *By* Dr. H. MARSHALL.

10. *Report of the Committee on the Bibliography of Spectroscopy.* See Reports, p. 192.

11. *Report of the Committee on the Action of Light on the Hydracids of the Halogens in the Presence of Oxygen.*—See Reports, p. 192.

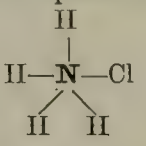
12. *Report of the Committee on the Proximate Constituents of the Various Kinds of Coal.*—See Reports, p. 264.

13. *Note on Valency or Atomicity.* *By* WM. DURHAM, *F.R.S.E.*

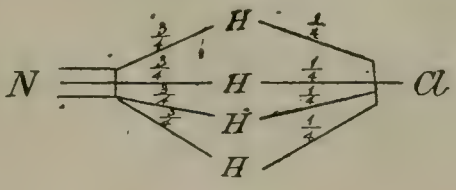
The author referred to several communications which he had made to the Royal Society of Edinburgh many years ago, and to a paper in the 'Revue des Sciences Générales' for June last, by Professor Schutzenberger, of the Royal College of France, who puts forth views identical with the author's.

Although it is quite true that the constitution of matter is atomic, there is no evidence to show that the chemical affinity associated with these atoms acts in units or in an atomic manner, but that on the contrary it acts within certain limits in all proportions, and may be all exhausted in combination, or part of it may be left as a residue too weak to produce a further undoubted chemical compound, but yet of sufficient energy to produce the phenomena of solution.

Take, for instance, NH_3. From this compound it is inferred that nitrogen is a triad, but it is found that this substance can combine with other two monad elements, viz., HCl. To explain this it is said that nitrogen acts sometimes as a pentad, and the resultant compound is represented thus:—



This must mean that the nitrogen, although already combined with three hydrogen atoms, and presumably possessing less chemical affinity than when free, has yet sufficient energy left, not only to combine with one additional atom of H and one of Cl, but also to dissociate the atoms of H and Cl combined as HCl. From the known affinities of the substances concerned this appears to the author to be incredible, and Professor Schutzenberger is of the same opinion. Analogous difficulties are found in double salts, such as the chlorides of platinum and potassium, &c. The solution of all these difficulties and many others of a like nature is very simple if it be admitted that chemical affinity is exercised, not in units, but as it were all round in any proportion, according to circumstances. Thus NH_4Cl may be represented graphically thus, without supposing any residual affinity whatever, although the author believes there is such:—



Analogous arrangements would represent the double chlorides. These examples were given in the author's original paper eleven years ago, and are the same as those which were given by Professor Schutzenberger in June last.

In 1878, in another paper, the author stated that from the behaviour of clay in water and other experiments he had come to the conclusion that in chemical compounds the affinity is not all exhausted in all cases, but that sometimes enough remained to give rise to solution and suspension phenomena, and that there is a regular gradation between chemical combination, solution, and suspension. The idea of residual affinity has now been adopted by many chemists, and lately Messrs. Picton and Linders, from experiments on solution of sulphites, have also come to the conclusion that there is no hard-and-fast line between solution and suspension. This confirms the conclusion which the author drew from his experiments of fourteen years ago.

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14. *On a Method for Determining the Vapour-pressures of Solutions.* *By* THOMAS EWAN, *B.Sc., Ph.D.*, 1851 *Exhibition Scholar at the Owens College, and* W. R. ORMANDY, *Bishop Berkeley Fellow at the Owens College.*

M. G. Charpy has pointed out in the 'Comptes Rendus' for 1890, p. 111, the possibility of using a condensation hygrometer of Regnault's form for the determination of the vapour-pressures of solutions. The paper contains a description of some experiments which we have made with this method.

The solution to be examined was placed in a cylindrical vessel, 4·5 cm. in diameter and 13·5 cm. long, with a narrower neck 20 cm. long. The solution was stirred by means of a ring of platinum wire attached to a light glass rod. The hygrometer, consisting of a single silver cup attached to a glass tube 22 cm. long, slipped loosely into the vessel containing the solution, was suspended about half an inch above its surface.

The whole apparatus was placed in a water-bath, which could be kept at a constant temperature.

The readings of the dew-point were made by observing the temperature at which the first traces of dew appeared on the hygrometer. The vapour-pressure of water corresponding to the temperature of the dew-point was taken from Regnault's tables. The number so obtained is the vapour-pressure of the solution at the temperature of the water-bath.

The accuracy of the method was tested by a number of readings with

(*a.*) Water.

(*b.*) Solutions of NaCl and $CuCl_2$.

Table I. contains the readings made with water; the dew-point should coincide with the temperature of the water.

TABLE I.

Temperature of Water	Dew-point	Difference
18·39	18·39	·00
18·40	18·40	·00
18·40	18·42	+·02
18·41	18·42	+·01
18·30	18·29	−·01
18·29	18·27	−·02

Sodium Chloride.

Table II. contains a comparison of the values of f/f' (f being the vapour-pressure of water, and f' that of the solution) obtained by ourselves and by other observers. C is the concentration of the solution in gramme molecules of NaCl in 1,000 grammes of water.

TABLE II.

	f/f'			
C	Dieterici	Tammann	Emden	Ewan and Ormandy
1	1·036	1·033	1·039	1·036
2	1·074	1·073	1·080	1·072
3	1·120	1·118	1·127	1·117
4	1·176	1·171	1·187	1·181
5	1·241	1·232	1·252	1·247
6	1·315	1·302	—	1·310

Copper Chloride.

In Table III. the vapour-pressures of solutions containing ·05, ·1, and ·2 gramme of $CuCl_2$ in one gramme of water (interpolated from our observations) are compared with those calculated from the heats of dilution of solutions of $CuCl_2$ by the method adopted by Kirchhoff (Pogg. 'Ann.,' civ. 612). In the tables, t = the temperature, 'f' calculated' = the vapour-pressures calculated by Kirchhoff's formula, and 'f' found' that obtained from our observations.

TABLE III.

$s = ·05$			
t	f' found	f' calculated	Difference
− 1·905	3·935	3·925	+·010
+14·5	12·039	12·041	−·002
16	13·263	13·253	+·010
18	15·033	15·037	−·004
$s = ·1$			
t	f' found	f' calculated	Difference
− 4·12	3·258	3·261	−·003
+14·5	11·776	11·777	−·001
16	12·981	12·964	+·017
18	14·706	14·711	−·005
$s = ·2$			
t	f' found	f' calculated	Difference
−9·63	1·957	2·044	−·087
14·5	11·243	11·208	+·035
16	12·389	12·370	+·019
18	14·035	14·042	−·007

Section C.—GEOLOGY.

President of the Section—Professor C. Lapworth, F.R.S., F.G.S.

The President delivered the following Address on Monday, August 8:—

It has, I believe, been the rule for the man who has been honoured by election to the Chair of President of the Geological Section of the British Association to address its members upon the recent advances made in that branch of geology in which he has himself been most immediately interested. It is not my intention upon the present occasion to depart from this time-honoured custom; for it has both the merit of simplicity and the advantage of utility to recommend it. In this way each branch of our science, as it becomes in turn represented, not only submits to the workers in other departments a report of its own progress, but presents by implication a broad sketch of the entire geological landscape, seen through the coloured glasses, it may be, of divisional prejudice, but at any rate instructive and corrective to the workers in other departments, as being taken from what is to them a novel and an unfamiliar point of view.

Now every tyro in geology is well aware of the fact that the very backbone of geological science is constituted by what is known as stratigraphical geology, or the study of the geological formations. These formations, stratified and unstratified, build up all that part of the visible earth-crust which is accessible to the investigator. Their outcropping edges constitute the visible exterior of our globe, the terraqueous surface of which forms the physical geography of the lands of the present day; and their internal characters and inter-relationships afford us our only clues to the physical geographies of bygone ages. Within them lies enshrined all that we may ever hope to discover of the history and the development of the habitable world of the past.

These formations are to the stratigraphical geologist what species are to the biologist, or what the heavenly bodies are to the astronomer. It was the discovery of these formations which first elevated geology to the rank of a science. In the working out of their characters, their relationships, their development, and their origin, geology finds its means, its aims, and its justification. Whatever fresh material our science may yield to man's full conception of nature, organic and inorganic, must of necessity be grouped around these special and peculiar objects of its contemplation.

When the great Werner first taught that our earth-crust was made up of superimposed rock-sheets, or formations, arranged in determinable order, the value of his conclusions from an economic point of view soon led to their enthusiastic and careful study; and his crude theory of their successive precipitation from a universal chaotic ocean disarmed the suspicions of the many until the facts themselves had gained such a wide acceptance that denial was no longer possible. But when the greater Hutton asserted that each of these rock-formations was in reality nothing more or less than the recemented ruins of an earlier world, the prejudices of mankind at large were loosed at a single stroke. Like Galileo's assertion of the movement of the globe, this demanded such

a simple and apparently undignified mode of creation that there is no wonder that, even down to the present day, there still exist some to whom this is a hard saying, to be taken, if taken at all, in homœopathic doses and with undisguised reluctance.

Hutton as regards his philosophy was, as we know, far in advance of his time. With all the boldness of conviction he unflinchingly followed out his ideas to their legitimate results. He claimed that as the stratified formations were composed of similar materials—sands, clays, limestones, and muds—to those now being laid down in the seas around our present coasts, they must, like them, have been the products of the ordinary natural agencies—of rain, rivers, and sea waters, internal heat and external cold—acting precisely as they act now. And, further, that as these formations lie one below the other, in apparently endless downward succession, and are all formed more or less of these fragmentary materials, so the present order of natural phenomena must have existed for untold ages. Indeed, to the continuance of this order, he frankly admits 'I see no trace of a beginning or sign of an end.'

The history of the slow acceptance of Hutton's doctrines, even among geologists, is, of course, perfectly familiar to us all. William Smith reduced the disputed formations to order, and showed that not only was each composed of the ruins of a vanished land, but that each contained in its fossils the proof that it was deposited in a vanished sea inhabited by a special life creation. Cuvier followed, and proved that the fossilised relics of these departed beings were such as made it absolutely unquestionable that these creatures might well have inhabited the earth at the present day. Lyell completed the cycle by demonstrating stage by stage the efficiency of present natural agencies to do all the work required for the degradation and rebuilding of the formations. Since his day the students of stratigraphical geology have universally acknowledged that in the study of present geographical causes lies the key to the geological formations and to the inorganic world of the past.

In this way the road was paved for Darwin and the doctrine of descent. The aid which had been so ungrudgingly afforded by biology to geology was repaid by one of the noblest gifts ever made by one science to another. For the purposes of geology, the science of biology had practically completed a double demonstration: first, that the extinct life discernible in the geological formations was linked inseparably with the organic life of the present; and, second, that every fossil recognised by the geologist was the relic of a creature that might well have existed upon the surface of the earth at the present time. Geology repaid its obligation to biology by the still greater twofold demonstration: first, that in the economy of nature the most insignificant causes are competent to the grandest effects, if only a sufficiency of time be granted them; and, second, that in the geological formations we have the evidences of the actual existence of those mighty eons in which such work might be done.

The doctrine of organic evolution would always have remained a metaphysical dream had geology not given the time in which the evolution could be accomplished. The ability of present causes to bring about slow and cumulative changes in the species is, to all intents and purposes, a biological application of Hutton's ideas with respect to the origin of the geological formations. Darwin was a biological evolutionist, because he was first a uniformitarian geologist. Biology is pre-eminent to-day among the natural sciences, because its younger sister, Geology, gave it the means.

But the inevitable consequence of the work of Darwin and his colleagues was that the centre of gravity, so to speak, of popular regard and public controversy, was suddenly shifted from stratigraphical geology to biology. Since that day stratigraphical geology, to its great comfort and advantage, has gone quietly on its way unchallenged, and all its more recent results have, at least by the majority of the wonder-loving public, been practically ignored.

Indeed, to the outside observer it would seem as if stratigraphical geology for the last thirty years had been practically at a standstill. The startling discoveries and speculations of the brilliant stratigraphists of the end of the last century and

the first half of the present, forced the geology of their day into the very front rank of the natural sciences, and made it perhaps the most conspicuous of them all in the eyes of the world at large. Since that time, however, their successors have been mainly occupied in completing the work of the great pioneers. The stratigraphical geologists themselves have been almost wholly occupied in laying down upon our maps the superficial outlines of the great formations, and working out their interrelationships and subdivisions. At the present day the young stratigraphical student soon learns that all the limits of our great formations have been laid down in our maps and textbooks, and finds but little to add to the accepted nomenclature of the time.

Our palæontologists, also, have equally busied themselves in working out the rich store of the organic remains of the geological formations; and the youthful investigator soon discovers that almost every fossil he is able to detect in the field has already been named, figured, and described, and its place in the geological record more or less accurately fixed.

In France, in Germany, in Norway, Sweden, and elsewhere, in Canada and in the United States, work as thorough and as satisfactory has been accomplished, and the local development of the great stratified formations and their fossils has been laid down with detail and clearness.

Many an unfledged but aspiring geologist, alive to these facts, and contrasting the well-mapped ground of the present time with the virgin lands of the days of the great pioneers, finds it hard to stifle a feeling of keen regret that there are, nowadays, no new geological worlds to conquer, no new systems to discover and name, and no strange and unexpected faunas to unearth and bring forth to the astonished light of day. The youth of stratigraphical geology, with all its wonder and freshness, seems to have departed, and all that remains is to accept, to commemorate, and to round off the glorious victories of the dead heroes of our science.

But to the patient stratigraphical veteran, who has kept his eyes open to discoveries new and old, this lull in the war of geological controversy presents itself rather as a grateful breathing time; the more grateful as he sees looming rapidly up in front the vague outlines of those oncoming problems which it will be the duty and the joy of the rising race of young geologists to grapple with, and to conquer, as their fathers met and vanquished the problems of the past. He knows perfectly well that geology is yet in her merest youth, and that to justify even her very existence there can be no rest until the whole earth-crust and all its phenomena, past, present, and to come, have been subjected to the domain of human thought and comprehension. There can be no more finality in geology than in any other science; the discovery of to-day is merely the stepping-stone to the discovery of to-morrow; the living theory of to-morrow must be nourished by the relics of its parent theory of to-day.

Now if we ask what are these formations which constitute the objects of study of the stratigraphical geologist, I am afraid that, as in the case of the species of the biologist, no two authorities would agree in framing precisely the same definition. The original use of the term *formation* was of necessity lithological, and even now the name is most naturally applied to any great sheet of rock which forms a component member of the earth-crust; whether the term be used specifically for a thin homogeneous sheet of rock like the Stonesfield slate, ranging over a few square miles; or generically, for a compound sheet of rock, like the Old Red Sandstone many thousands of feet in thickness, but whose collective lithological characteristics give it an individuality recognisable over the breadth of an entire continent.

When Werner discovered that the 'formations' of Saxony followed each other in a certain recognisable order, a second characteristic of a formation became superposed upon the original lithological conception—namely, that of determinate 'relative position.' And when William Smith proved that each of the formations of the English Midlands was distinguished by an assemblage of organic remains peculiar to itself, there became added yet a third criterion—that of the possession of 'characteristic fossils.'

But these later superposed conceptions of time-succession, and life-type, are far better expressed by dividing the geological formations, on the one hand, into zoological *zones*, and grouping them together, on the other hand, into chronological *systems*. For in the experience of every geologist he finds his mind instinctively harking back to the bare lithological application of the word 'formation,' and I do not see that any real advantage is gained by departing from the primitive use of the term.

A *zone*, which may be regarded as the *unit* of *palæontological succession*, is marked by the presence of a special fossil, and may include one or many subordinate formations, or only a part of a formation. A *system*, which is, broadly speaking, the *unit of geological succession*, includes many 'zones,' and often, but not always, many 'formations.' A *formation*, which is the *unit of geological stratigraphy*, is a rock sheet composed of many strata possessing common lithological characters. The formation may be simple, like the Chalk, or compound, like the New Red Sandstone, but, simple or compound, local or regional, it must be always recognisable, geographically and geologically, as a lithological individual.

As regards the natural grouping of these lithological individuals as such, fair progress has been made of late years, and our information is growing apace. We know that there are at any rate three main groups: First, the stratified formations due to the action of moving water above the earth-crust; second, the igneous formations which are derived from below the earth-crust; third, the metamorphic formations which have undergone change within the earth-crust itself. We know also that of these three the only group which has hitherto proved itself available for the purpose of reading the past history of the globe is that of the stratified formations.

Studying these stratified formations therefore in greater detail, we find that they fall naturally in their turn into two sets, viz., a mechanical set of pebble beds, sandstones and clays, formed of rock fragments, washed off the land into the waters, and an organic set of limestones, chalk, &c., formed of the shells and exuviæ of marine organisms.

But when we attempt a further division of these two sets, our classification soon begins to lose its definiteness. We infer that some formations, such as the Old Red and the Triassic, were the comparatively rapid deposits of lakes and inland seas; that others, like the Coal Measures, London Clay, &c., were the less rapid deposits of lagoons, river valleys, deltas, and the like; that others, like our finely laminated shales and clays of the Silurian and Jurassic, were the slower deposits of the broader seas; and finally, that others, like our Chalk and Greensand, were possibly the extremely slow deposits of the more oceanic deeps.

Nevertheless, after looking at the formations collectively, there remains no doubt whatever in the mind of the geologist that their mechanical members are the results of the aqueous degradation of vanished lands, and that their organic members are the accumulated relics of the stony secretions of what once were living beings. Neither is there any possibility of escape from the conclusion that they have all been deposited by water in the superficial hollows—the lakes, the sea-bottoms, and the ocean floors—of the earth-crust of their time.

In the life of every individual stratified formation of the mechanical type we can always distinguish three stages: first, a stage of erosion and transportation, in which the rock fragments were worn off the rocks of the higher ground and washed down by rain and rivers to the sea; second, a stage of deposition and consolidation below the surface of the quiet waters; and third, a final stage in which the completed rock-formation was bent and upheaved, in part at least, into solid land. In the formations of the organic type three corresponding stages are equally discernible: first, the period of mineral secretion by organised beings; second, the period of deposition and consolidation; and third, the final period of local elevation in mass. But one and all, mechanical and organic alike, the formations bear in their composition, in their arrangement, and in their fossils, abundant and irresistible evidences that they *were* the products, and that they *are* the memorials of the physical geography of their time.

Guided by the principles of Hutton and Lyell, geologists have worked out with great care and completeness the effects of those agencies which rule in the first

of these three life-stages in the history of a mechanical formation. No present geological processes are better known to the young geologist than those of denudation, erosion, and transportation, so familiar to us in the eloquent works of our President. They form together the subject-matter of that most wonderful and fascinating chapter in geology which, from its modest opening among the quiet Norfolk sandhills, sweeps upwards and onwards without a break to its magnificent close on the brink of the gorge of the Colorado. But our knowledge of the detailed processes of deposition and consolidation which rule in the second stage is still exceedingly imperfect, although a flood of light has been thrown upon the subject by the brilliant results of the *Challenger* Expedition. And we are compelled to admit that our knowledge of the operations of those agencies which rule in the processes of upheaval and depression is as yet almost nil; and what little we have already learnt of the effects of those agencies is the prey of hosts of conflicting theories that merely serve to annoy and bewilder the working student of the science.

But not one of the formative triad of detrition, deposition, and elevation can exist without the others. No detrition is possible without the previous upheaval of the rock-sheet from which material can be removed; no deposition is possible without the previous depression of the rock-sheet which forms the basin in which the fragmentary material can be laid down.

Our knowledge, therefore, of the origin and meaning of any geological formation whatever can at most be only fragmentary until this third chapter in the life-history of the geological formation has been attacked in earnest.

Now, all the rich store of knowledge that we possess respecting the first stage in the life of a geological formation has been derived from a comparison of the phenomena which the stratigraphical geologist finds in the rock formations of the past, with correspondent phenomena which the physical geographer discovers on the surface of the earth of the present. And all that we know of the second stage has been obtained in precisely the same way. Surely analogy and common sense both teach us that all which is likely to be of permanent value to us as regards the final stage of elevation and depression must first be sought for in the same direction.

Within the last twenty years or so many interesting and vital discoveries have been made in the stratigraphy of the rock formations that bear largely upon this obscure chapter of elevation and depression. And I propose on this occasion that we try to summarise a few of these new facts; and, reading them in conjunction with what we actually know of the physical geography of the present day, try to ascertain how such mutual agreement as we can discover may serve to aid the stratigraphical geologist in his interpretation of the true meaning of the geological formations themselves. We may not hope for many years to come to read the whole of this geological chapter, but we may perhaps modestly essay an interpretation of one or two of the opening paragraphs.

In the physical geography of the present day, we find the exterior of our terraqueous globe divided between the two elements of land and water. We know that the solid geological formations exist everywhere beneath the visible surface of the lands, but of their existence under the present ocean floor we have as yet no absolute certainty. We know both the form of the surface and the composition of the outer layers of the continental parts of the lithosphere; we only know as yet even in outline the form of the surface of its oceanic portions.

The surface of each of our great continental masses of land resembles that of a long and broad arch-like form, of which we see the simplest type in the New World. The surface of the North American arch is sagged downwards in the middle into a central depression which lies between two long marginal plateaux; and these plateaux are finally crowned by the wrinkled crests which form its two modern mountain systems. The surface of each of our ocean floors exactly resembles that of a continent turned upside down. Taking the Atlantic as our simplest type, we may say that the surface of an ocean basin resembles that of a mighty trough or syncline, buckled up more or less centrally into a medial ridge, which is bounded by two long and deep marginal hollows, in the cores of which still deeper grooves

sink to the profoundest depths. This complementary relationship descends even to the minor features of the two. Where the great continental sag sinks below the ocean level, we have our gulfs and our Mediterraneans, seen in our type continent as the Mexican Gulf and Hudson Bay. Where the central oceanic buckle attains the water-line we have our oceanic islands, seen in our type ocean as St. Helena and the Azores. Although the apparent crust-waves are neither equal in size nor symmetrical in form, this complementary relationship between them is always discernible. The broad Pacific depression seems to answer to the broad elevation of the Old World—the narrow trough of the Atlantic to the narrow continent of America.

Every primary wave of the earth's surface, again, is broken up into minor waves, in each of which the ridge and its complementary trough are always recognisable. The compound ridge of the Alps answers to the compound Mediterranean trough: the continuous western mountain chains of the Americas to the continuous hollow of the Eastern Pacific which bounds them; the sweep of the crest of the Himalaya to the curve of the Indo-Gangetic depression. Even where the surface waves of the lithosphere lie more or less buried beneath the waters of the ocean and the seas, the same rule always obtains. The island chains of the Antilles answer to the several Caribbean abysses, those of the Ægean Archipelago answer to the Levantine deeps.

Draw a section of the surface of the lithosphere along a great circle in any direction, the rule remains always the same: crest and trough, height and hollow, succeed each other in endless sequence, of every gradation of size, of every degree of complexity. Sometimes the ridges are continental, like those of the Americas; sometimes orographic, like those of the Himalaya; sometimes they are local, like those of the English Weald. But so long as we do not descend to minor details we find that every line drawn across the earth's surface at the present day rises and falls like the imaginary line drawn across the surface of the waves of the ocean. No rise of that line occurs without its complementary depression; the two always go together, and must of necessity be considered together. Each pair constitutes one of those *geographical units of form* of which every continuous direct line carried over the surface of the lithosphere of our globe is made up. This unit is always made up of an arch-like rise and a trough-like depression, which shade into each other along a middle line of contrary curvature. It resembles the letter S or Hogarth's line of beauty, and is clearly similar in form to the typical wave of the physicist. Here, then, we reach a very simple and natural conclusion: viz., the surface of the earth-crust of the present day resembles that of a series of crust-waves of different lengths and different amplitudes, more or less irregular and complex, it is true, but everywhere alternately rising and falling in symmetrical halves like the waves of the sea.

Now this rolling wave-like earth-surface is formed of the outcropping edges of the rock formations which are the special objects of study of the stratigraphical geologist. If, therefore, the physiognomy of the face of our globe is any real index of the character of the personality of the earth-crust beneath, these collective geographical features should be precisely those which answer to the collective structural characters of the geological formations.

In the earlier days of geology one of the first points recognised by our stratigraphists was the fact that the formations were successive lithological sheets, whose truncated outcropping edges formed the present surface of the land, and that these sheets lay inclined at an angle one over the other, or, as William Smith quaintly expressed it, like a tilted 'pile of slices of bread-and-butter.' But as discovery progressed, the explanation of this arrangement soon became evident. The formations revealed themselves as a series of what had originally been deposited as horizontal sheets, lying in regular order one over the other, but which had been subsequently bent up into alternating arches and troughs (the anticlines and synclines of the geologist). Their visible parts, which now constitute the surface of our habitable lands, are simply those parts of the formations which are cut by the irregular plane of the present earth surface. All those parts of the great arches and troughs, formerly occurring above that plane, have been removed by denu-

dation; all those parts below that plane lie buried still, out of sight within the solid earth-crust.

Although in every geological section of sufficient extent it was seen that the anticline or arch never occurred without the syncline or trough—in other words, that there was never a rise without a corresponding fall of the stratum—yet it is only of late years that the stratigraphical geologist has come clearly to recognise the fact that the anticline and syncline must be considered together, and must be united as a single crust-wave. For the arch is never present without its complementary trough, and the two together constitute the *tectonic, structural, or orographic unit*, namely, *The Fold*, the study of which, so brilliantly inaugurated by Heim in his 'Mechanismus der Gebirgsbildung,' is destined, I believe, in time, to give us the clue to the laws which rule in the local elevation and depression of the earth-crust, and to furnish us with the means of discovery of the occult causes that lie at the source of those superficial irregularities which give to the face of our globe its variety, its beauty, and its habitability.

Like the form of the surface wave of the geographer, the form of this wave or fold of the geologist resembles that of the wave of the physicist. Now we may regard such a wave as formed of two parts, the arch-like part above, and the trough-like part below. The length of the wave is naturally the length of the axial line joining the outer extremities of the arch and trough, and passing through the centre, node, or point of origin, of the wave itself, which bisects the line of contrary curvature. The amplitude of the wave is the height of the arch added to the depth of the trough. The arch part of such a wave, if perfectly symmetrical, may clearly be regarded as belonging either to a wave travelling to the right, in which case the complementary trough is the one in that direction; or it may be regarded as belonging to a wave travelling to the left, in which case its trough must be the one in that direction. But as in the case of the shore wave, the advancing slope of the wave is always the steeper, and the real centre of the wave must lie half-way down this steeper slope, so also, in the case of the geological fold, there is no difficulty in recognising the centre or in fixing the real direction of movement.

The fold of the geologist differs from the ordinary wave of the physicist, essentially in the fact that, even in its most elementary conception, as that of a plate bent by pressure applied from opposite sides, it necessarily includes the element of thickness. And this being the case, the rock sheet which is being folded and curved has different layers of its thickness affected differently. In the arch of the fold the upper layers of the rock sheet are extended, while its lower layers are compressed. On the contrary, in the trough of the fold the upper layers are compressed, and the lower layers are extended. But in arch and trough alike there exists a central layer, which, beyond taking up the common wave-like form, remains practically unaffected.

But the geological fold has, in addition to length and thickness, the further element of breadth, and this fact greatly complicates the phenomena.

Many of the movements which take place in a rock sheet which is being folded, or in other words those produced by the bending of a compound sheet composed of many leaves, can be fairly well studied in a very simple experiment. Take an ordinary large note-book, say an inch in thickness, with flexible covers. Rule carefully a series of parallel lines across the edges of the leaves at the top of the book, about $\frac{1}{8}$ of an inch apart, and exactly at right angles to the plane of the cover. Then, holding the front edges loosely, press the book slowly from back and front into an S-like form until it can be pressed no further. As the wave grows, it will be noticed that the cross lines which have been drawn on the upper edge of the book remain fairly parallel throughout the whole of the folding process, except in the central third of the book, where they arrange themselves into a beautiful sheaf-like form, showing how much the leaves of the book have sheared or slidden over each other in this central portion. It will also be seen when the S is complete that the book has been forced into a third of its former breadth. It is clear that the wave which the book now forms must be regarded as made up of three sections: viz., a section forming the outside of the trough on the one side, a

section forming the outside of the arch on the other, and a central or common section, which may be regarded either as uniting or dividing the other two.

As this experiment gives us a fair representation of what takes place in a geological fold, we see at a glance that the geologist is forced to divide his fold into three parts—an arch limb, a trough limb, and a middle limb—which latter we may call the *copula* or the *septum*, according as we regard it as connecting or dividing the other two. Our note-book experiment, again, shows us also that in the trough limb and the arch limb the leaves or layers undergo scarcely any change of relative position beyond taking on the growing curvature of the wave. But the layers in the central part, or *septum*, undergo sliding and shearing. It will be found also, by gripping the unbound parts of the book firmly, and practising the folding in different ways, that this *septum* is also a region of warping and twisting. This simple experiment should be practised again and again until these points are clear, and the various stages of the folding process become apparent, the surface of the book being forced first into a gentle arch-like rise with a corresponding trough-like fall; then stage by stage the arch should be pushed over on to the trough until the surfaces of the two are in contact, and the book can be folded no further.

In the structure of our modern mountain ranges we discover the most beautiful illustrations of the bending and folding of the rocky formations of the earth-crust. The early results of Rogers among the Alleghanies, of Lory and Favre in the Western Alps, have been greatly extended of late years by the discoveries of Heim and Baltzer in the Central Alps, of Bertrand in Provence, of Margerie in Languedoc, of Dutton and his colleagues in the western ranges of America, and of Peach and Horne and others in the older rocks of Britain. The light these researches throw upon the phenomena of mountain structure will be found admirably summarised and discussed in the works of Leconte, of Dana, of Daubrée, of Reade, of Heim, and finally in the magnificent work of Suess, the 'Antlitz der Erde,' of which only the first two volumes have yet appeared.

Looking first at the mountain fold in its simplest form as that of a bent rock-plate, composed of many layers which have been forced into two similar arc-like forms, the convexities of which are turned the one upwards and the other downwards, we find in the present mountain ranges of the globe every kind represented. We commence with one in which the arch is represented merely by a gentle swell of the rock sheet, and the trough by an answering shallow depression, the two shading into each other in an area of contrary flexure. From this type we pass insensibly to others in which we see that the sides of the common limb or septum are practically perpendicular. From these we pass to folds in which the twisted common limb or septum overhangs the vertical, and so on to that final extreme where the arch limb has been pushed completely over on to the trough limb, and all three members, as in our note-book experiment, are practically welded into one conformable solid mass.

In many cases, due partly to the action of transverse pressures, the septum becomes reduced to a plane of contrary motion or thrust-plane; and the arch limb and trough limb slide over each other as two solid masses. But here we have no longer a fold, but a fault.

Although the movements of these mountain folds are slow and insensible, and only effected in the course of ages, so that little or no evidence of the actual movement of any single one of them has been detected since they were first studied, yet it is perfectly plain that when we regard them collectively, we have here crust folds in every stage of their existence. Each example in itself represents some one single stage in the lifetime of a single fold. They are simply crust folds of different ages. Some are, as it were, just born; others are in their earliest youth. Some have just attained their majority, some are in the prime of life, and some are in the decrepit stages of old age. Finally, those in which all three members—arch limb, trough limb, and septum—are crushed together into a single mass are dead. Their life of individual movement is over. If the earth pressure increases the material which they have packed together may of course form a passive part of a later fold, but they themselves can move no more.

We see that every mountain fold commences first as a gentle alternate eleva-

tion and depression of one or more of the component sheets of the geological formations which make up the earth-crust. This movement is due apparently to the tangential thrusts set up by the creeping together, as it were, of those neighbouring and more resistant parts of the earth-crust which lie in front of and behind the moving wave. Yielding slowly to these lateral thrusts the crest of the fold rises higher and higher, the trough sinks lower and lower, the central common limb grows more and more vertical, and becomes more and more strained, sheared, and twisted. As this middle limb yields, the rising arch part of the fold is forced gradually over on to the sinking trough, until at last all three members come into conformable contact, and further folding as such is impossible. Movement ceases; the fold is dead. We see also from our note-book experiment that the final result of the completion of the fold is clearly to strengthen up and consolidate that part of the crust plate to the local weakness of which it actually owed its origin and position. The fold has by its life-action theoretically trebled the thickness of that part of the earth-plate in which its dead remains now lie. If the lateral pressure goes on increasing, and the layers of the earth-crust again begin to fold in the same region, the inert remains of the first fold can only move as a passive part of a newer fold, either as a part of the new arch-limb, the new trough-limb, or the new septum. As each younger and younger fold formed in this way necessarily includes a more resistant, and therefore a thicker, broader, and deeper sheet of the earth-crust, we have here the phylogenetic evolution of a whole family of crust folds, each successive member of which is of a higher grade than its immediate predecessor.

But it very rarely happens that the continuous plate in which any fold is imbedded is able to resist the crust-creep until the death of the first fold. Usually, long before the first simple fold is completed, a new and a parallel one rises in front of it normally on the side of the trough limb; and the two grow, as it were, henceforward, side by side. But the younger fold, being due to a greater pressure than the older, must of necessity be of a higher specific grade, and the two together form a generic fold in common.

Our present mountain systems are all constituted of several families of folds, formed in this way, of different gradations of size, of different dates of origin, and of different stages of life evolution; and in each family group the members are related to each other by this natural genetic affinity.

Sometimes the new folds are formed in successive order only on one side of the first fold, and then we have our unilateral (or so-called unsymmetrical) mountain groups, like those of the Jura and the Bavarian Alps. Sometimes they are formed on both sides of the original fold, and then we have our bilateral (or so-called symmetrical) ranges, like the Central Alps. In both cases the septa of the aged or dead folds are of necessity all directed inwards towards the primary fold. If, therefore, they originate only on one side of the fold, our mountain group looks unsymmetrical, with a very steep side opposed to a gently sloping side. If they grow on both sides of the original fold, we have the well-known 'fan structure' of mountain ranges. In this case the whole complex range is seen at a glance to be a vast compound arch of the upper layers of the earth-crust, keyed up by the material of the dead or dying folds, which, by the necessities of the case, constitute mighty wedges, whose apices are directed inwards towards the centres of the system. But a complete arch of this kind is in reality not a single fold, but a double one, with a septum on both sides of it, and it requires two troughs, one on each side of it, as its natural complement. The so-called unsymmetrical ranges, therefore, which are constituted merely of arch limb, trough limb, and septum, are locally the more natural and the more common.

It is clear that in the lifetime of any single fold, its period of greatest effective energy and most rapid movement must be that of middle life. In early youth the lateral pressure is applied at a very small angle, and the tangential forces act therefore under the most disadvantageous circumstances. In the middle life of the fold the arch limb and the trough limb stand at right angles to the septum, and the work of deformation is then accomplished under the most favourable mechanical conditions, and with the greatest rapidity. That is to say, the activity of the fold

and the rate of movement of the septum, like the speed of the storm wind, vary directly as the gradient.

In our note-book experiment we observed that little or no change took place in the arch limb and trough limb, while the septum became remarkably sheared and twisted. The same is the case in nature; but here we have to recollect that these moving mountain folds are of enormous size, indeed actual mountains in themselves. These great arches, scores of miles in length, thousands of feet in height and thickness, must of necessity be of enormous weight, capable of crushing to powder the hardest rocks over which they move, while the thrust which drives them forward is practically irresistible. It is plain, therefore, that, while the great arch limb and the trough limb of one of these mighty folds move over and under each other from opposite directions, they form in conjunction an enormous machine, composed of two mighty rollers or millstones, which mangle, roll, tear, squeeze, and twist the rocky material of the middle limb or septum that lies jammed in between them into a laminated mass. This deformed material, which is the characteristic product of the mountain-making forces, is, of course, made up of the stuff of the original middle limb of the fold; and whether we call it breccia, mylonite, phyllite, or schist, although it may be composed of sedimentary stuff, it is certainly no longer a *stratified* rock; and though it may have been originally purely igneous material, it is certainly no longer *volcanic*. It is now a manufactured article made in the great earth mill.

These mountain folds, however, are merely the types of folds and wrinkles of all dimensions which affect the rock formations of the earth-crust. Within the mountain chains themselves we can follow them fold within fold, first down to formations, then to strata, then to laminæ, till they disappear at last in microscopic minuteness beyond the limits of ordinary vision. Leaving these, however, for the moment, let us travel rather in the opposite direction, for these mountain folds are by no means the largest known to the stratigraphical geologist. Look at any geological section crossing our type continent of North America, and it will be found that the whole of the Rocky Mountain range on its western side and the Alleghany ranges on the eastern are really two mighty compound geological anticlines, while the central sag of the Mississippi Basin is a compound geological syncline made up of the whole pile of the geological formations. That is to say, the continent of North America is composed of a pair of geological folds, the two arches of which are represented by the Rockies on the one side and the Alleghanies on the other; while the intermediate Mississippi syncline is the common property of both. Here, then, we reach a much higher grade of fold than the orographic or mountain-making fold, viz., the plateau-making fold or the semi-continental fold, which, because of its enormous breadth, must include a very much thicker portion of the earth-crust than the ordinary orographic fold itself.

But which must be the actual middle limbs of these two American folds, the septal areas where most work is being done and the motion is greatest?

Taught by what we have already learnt of the mountain wave, the answer is immediate and certain. They must be the steeper sides of each of the two arches, namely, those which face the ocean. How perfectly this agrees with the geological facts goes without saying. It is on the steep Pacific side of the western fold that the crushing and crumpling of its rocks is the greatest. It is on the Atlantic side of the eastern fold that the contortion and metamorphism of its rocks are at their maximum; while in the common and gently sloping trough of both folds, namely, in the intermediate Mississippi Valley, the entire geological sequence remains practically unmodified throughout.

Again, which of these two American folds should be the more active at the present day? Taught by our study of the mountain wave, the answer again is immediate and conclusive. It must be that fold whose septum has the steeper gradient. Geology and geography flash at once into combination. The steeper Pacific septum of the western fold, from Cape Horn almost to Alaska, is ablaze with volcanoes, or creeping with earthquakes; while the gently inclined Atlantic septum of the eastern fold, from Greenland to Magellan Straits, shows none, except on the outer edge of the Antilles, in the very region where the slope of the septal surface

is the steepest. We see at a glance that the vigour of these two great continental folds, like those of our mountain waves, varies directly as the surface gradient of the septum.

But the geographical surface of North America, considered as a whole, is in reality that of a double arch with a sag or common trough in the middle. We have seen already that this double arch must be regarded as the natural complement of the equally double Atlantic trough. Here, then, if the path of analogy we have hitherto so triumphantly followed up to this point is still to guide us, the basin of the Atlantic must be, not only in appearance but in actuality, formed of two long minor folds of the same grade as the two that form the framework of America, but with their members arranged in reverse order. If so, their submarine septa ought also to be lines of movement and of volcanic action. And this is again the case. The volcanic islands of the Azores and St. Helena lie not exactly on the longitudinal crests of the mid-oceanic *Challenger* ridge, but upon its bounding flanks.

We have not yet, however, finished with our simple folds. If we draw a line completely round the globe, crossing the Atlantic basin at its shallowest, between Cape Verde and Cape St. Roque, and continued in the direction of Japan, where the Pacific is at its deepest, as the trace of a great circle, we find that we have before us a crust fold of the very highest and grandest order. We have one mighty continental arch stretching from Japan to Chili, broken medially by the sag of the Atlantic trough; and we see that this great terrestrial arch stands directly opposed to its natural complement, the great trough of the Pacific, which is bent up in the middle by the mightiest of all the submarine buckles of the earth-crust, on which stand the oceanic islands of the central Pacific.

But if this be true, then the septum of all septa on our present earth-crust must cross our grandest earth fold where the very steepest gradient occurs along this line, and it must constitute the centre-point of the moving earth fold, and of greatest present volcanic activity. And where is this most sudden of all depressions? Taught once more by our geological fold, the answer is instantaneous and incontrovertible. It is on the shores of Japan, the mightiest and most active of all the living and moving volcanic localities on the face of our globe.

But the course of the line which we indicated as forming our grandest terrestrial fold returns upon itself. It is an endless fold, an endless band, the common possession of two sciences. It is geological in origin, geographical in effect. It is the wedding ring of geology and geography, uniting them at once and for ever in indissoluble union.

Such an endless fold, again, must have an endless septum, which in the nature of things must cross it twice. Need I point out to the merest tyro in these wedded sciences that if we unite the Old and New Worlds, and Australia, with their intermediate sags of the Atlantic and the Indian Oceans, as one imperial earth-arch, and regard the unbroken watery expanse of the Pacific as its complementary depression, the circular coastal band of contrary surface-flexure which lies between them should constitute the moving master septum of the present earth-crust? This is the 'Volcanic Girdle of the Pacific,' our 'Terrestrial Ring of Fire.'

Or, finally, if we rather regard the compact arch of the Old World itself as the natural complement of the broken Indo-Pacific depression, then the most active and continuous septal band of the present day should divide them. Again, our law asserts itself triumphantly. It is the great volcanic and earthquake band on which are strung the Festoon Islands of Western Asia—the band of Mt. St. Elias, the Aleutians, Kamtchatka, and the Kuriles—the band of Fusijama, Krakatoa, and Sangir. The rate of movement of the earth's surface doubtless everywhere varies directly as the gradient.

We find, therefore, that even if we restrict our observations to the most simple and elementary conception of the rock fold, as being made up of arch-limb, trough-limb, and twisting but still continuous septum, we are able to connect in one unbroken chain the minutest wrinkle of the finest lamina of a geological formation with the grandest geographical phenomena on the face of our globe.

We find, precisely as we had anticipated, that the wave-like surface of the earth of

the present day reflects, in its entirety, the wave-like arrangement of the geological formations below. On the lands we find that the surface arches and troughs answer precisely to the grander regional anticlines and synclines of the subterranean sedimentary sequence; and it may, I believe, be regarded as certain that the submarine undulations have a similar or complementary relationship. We find in the New Geology, as Hutton found in the Old, that geography and geology are one. We discover, as we had suspected, that the physiognomy of the face of our globe is an unerring index of the solid personality beneath. It bears in its lineaments the peculiar family features and the common traits of its long line of geological ancestors.

Such, it seems to me, is an imperfect account of the introductory paragraphs of that great chapter in the New Geology which is now in course of interpretation by geologists of the present day, and we have translated them exactly in the old way by the aid of the only living geological language, namely, the language of present natural phenomena; and I doubt not that sooner or later the rest of the great chapter will be read by the same simple means.

I have strictly confined myself to-day to the discussion of the characteristics of the simple geological fold as reduced to its most elementary terms of arch, trough, and unbroken septum; for this being clearly understood, the rest naturally follows. But this twisted plate is really the key which opens the entire treasure-house of the New Geology, in which lie spread around, in bewildering confusion, facts, problems, and conclusions, enough to keep going the young stratigraphists and other scientists busily at work for many a long year to come.

Into this treasure-house I often wander myself, in the few leisure hours that I can steal from a very busy professional life; and out of it I bring now and again heresies that sometimes amuse and sometimes horrify my geological friends. As you have so patiently listened to what I have already said, perhaps you will permit me in a few final sentences to indicate in brief some of those novelties which I see already more or less clearly, and a few of those less novel points on which it appears to me that more light is wanted. My excuse is twofold—first, to furnish material for work and controversy to the young geologists; and, second, to obtain aid for myself from workers in other walks of science.

The account of the simple rock-fold which I have already given you is of the most elementary kind. It presupposes merely the yielding to tangential pressure from front and back, combined with effectual resistance to sliding. But in the layers of the earth-crust there is always, in addition, a set of tangential pressures theoretically at right angles to this. The simple fold becomes a *folded fold*, and the compound septum twists not only vertically but laterally. On the surface of the globe this double set of longitudinal and transverse waves is everywhere apparent. They account for the detailed disposition of our lands and our waters, for our present coastal forms, for the direction, length, and disposition of our mountain-ranges, our seas, our plains, and lakes. The compound arch becomes a dome, its complementary trough becomes a basin. The elevations and depressions, major and minor, are usually twinned, like the twins of the mineralogist, the complementary parts being often inverted, and turned through 180° (compare Italy with the Po-Adriatic depression). Every upward swirl and eddy has its answering downward swirl. The whole surface of our globe is thus broken up into fairly continuous and paired masses, divided from each other by moving areas and lines of mountain making and crust movement, so that the surface of the earth of the present day seems to stand midway in its structure and appearance between that of the sun and that of the moon, its eddies wanting the mobility of those of the one and the symmetry of those of the other. In the geology of the earth-crust, also, the inter-crossing of the two sets of folds, theoretically at right angles to each other, gives rise to effects equally startling. It lies at the origin of the thrust-plane or overfault, where the septal region of contrary motion in the fold becomes reduced to, or is represented by, a *plane* of contrary motion. It allows us to connect together under one set of homologies folds and faults. The downthrow side of the fault answers to the trough, the upthrow side to the arch, of our longitudinal fold; while the fault-plane itself

represents the septal area reduced to zero. The node of the fault and the alternation and alteration of throw are due to the effects of the transverse folding.

These transverse folds of different grades, which affect the various layers of the earth-crust differentially, account also for the formation of laccolites, of granitic cores, and of petrological provinces; and they enable us also to understand many of the more striking phenomena of metamorphism.

Of the folds of the third order I shall here say nothing; but I must frankly admit that the primal cause of all this tangential movement and folding stress is still as mysterious to me as ever. I incline to think that it is due to many causes—to tidal action, sedimentation, and many others. I cannot deny, however, that it may be *mainly* the result of the contraction in diameter of our earth, due to the loss of its original heat into outer space. For everywhere we find evidences of symmetrical crushing of the earth-crust by tangential stresses. Everywhere we find proofs that the various layers of that crust have been affected differentially, and the outer layers have been bent the most. We seem to be dealing not so much with a solid globe as with a globular shell composed of many layers.

Is it not just possible, after all, that, as others have suggested, our earth is such a hollow shell, or series of concentric shells, on the surface of which gravity is at a maximum, and in whose interior it is practically non-existent? May this not be so, also, in the case of the sun, through whose spot-eddies we possibly look into a hollow interior? If so, perhaps our present nebulæ may also be hollow shells formed of meteorites, on the surfaces of which shells the fiery spirals we see would be the swirls which answer to the many twisting crustal septa of the earth. Our comets, too, in this case might be elongated ellipsoids, whose visible parts would be merely interference phenomena, or sheets of differential movement.

In this case we have represented before us to-day the past of our earth as well as its present. Uniformity and Evolution are one.

Thus from the microscopic septa of the laminæ of the geological formations we pass outwards *in fact* to these moving septa of our globe, marked on the land by our new mountain-chains, and on the shores by our active volcanoes. Thence we sweep, *in imagination*, to the fiery eddies of the sun, and thence to the glowing swirls of the nebulæ; and so outwards and upwards to that most glorious septum of all the visible creation, the radiant ring of the Milky Way.

Professor George Darwin, in his Address to the Section of Mathematical and Physical Science at the meeting of the British Association at Birmingham in 1886, with all the courage of genius, and the authority of one of the sons of the prophets, acknowledged that it seems as likely that 'meteorology and geology will pass the word of command to cosmical physics as the converse.' Behind this generous admission I shelter myself. But I feel absolutely confident that, long after the physicists may have swept away these astronomical suggestions as 'the baseless fabric of a vision,' there will still remain in the treasure-house of the geological fold a wealth of abundant material for the use of the mathematician, the physicist, the chemist, the mineralogist, and the astronomer of the deepest interest and of the highest value.

THURSDAY, AUGUST 4.

The following Reports and Papers were read:—

1. *Report on Photographs of Geological Interest.*—See Reports, p. 290.

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2. *On the Glacial Distribution of the Riebeckite-Eurite of Ailsa Craig.* *By* Joseph Lomas, *Assoc. Roy. Coll. Science.*

The rock is a granophyre or eurite, and contains the rare blue variety of soda-hornblende, riebeckite. It has been found as a boulder in glacial deposits by Mr. P. F. Kendall, F.G.S., and the author in the Isle of Man and at Moel-y-Tryfaen;

by the author in Anglesey; at Liverpool, Garston, and Hale Head in Lancashire, and at Dawlpool and Birkenhead in Cheshire. The Rev. Mr. Barker, S.J., has recorded it from the Vale of Clwyd.

It is always accompanied by South Scottish granites, and where these predominate, as in the Isle of Man, it is common. About Liverpool the Scotch rocks are about in the same proportion as those of Lake District origin, and further east the Scotch cease altogether.

Floating ice could not have transported the Ailsa Craig and other northern rocks, as there is not a free intermingling of types. There is also a vertical uplift of over 200 feet from Ailsa Craig (1,140 feet) to Moel-y-Tryfaen (1,350 feet). The ridge of which Moel-y-Tryfaen forms a part acted as a barrier, and destroyed the force of the Snowdonian ice northwards, and thus the northern ice got the mastery and pushed the northern erratics up to the summit of Moel-y-Tryfaen.

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3. *Report of the Committee on Erratic Blocks.*—See Reports, p. 267.

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4. *The Cause of the Ice Age.*

By J. W. Gray, *F.G.S., and* Percy F. Kendall, *F.G.S.*

Two hypotheses at present engage the attention of glacialists, viz., *a*, that propounded by Croll, which ascribes the glacial cold to the combined effects of a high degree of eccentricity of the earth's orbit and the precession of the equinoxes, with, as secondary causes, changes in the winds and marine currents; and *b*, the explanation presented in detail by Mr. Warren Upham, which is based upon great earth-movements which might lift wide areas above the snow-line.

Neither of these appears to satisfy the known geological conditions, which may be defined as follows: (1) The Glacial period was a unique episode, no evidence being adducible of any previous Glacial period, but only of glacial conditions in the neighbourhood of mountains. (2) The cold conditions came on with extreme slowness, the refrigeration being progressive from the Eocene period to the climax. (3) The Glacial period was of long duration, judging by the great dimensions of the glaciers and the amount of work done by them. (4) The return to temperate conditions was very rapid. (5) The final disappearance of the ice was a very recent event; the condition of the drift accumulations and direct measurements such as those of the recession of waterfalls point to a maximum of 10,000 years.

Croll's hypothesis, in the opinion of the authors, is in opposition to Nos. 1, 2, 4, and 5.

Upham's explanation has much to commend it. Submerged valleys of comparatively recent date exist upon many coasts, *e.g.*, one which deeply indents the 1,000-fathom line at the mouth of the Congo; but the rate of filling up of these gulfs is not known, and they are not necessarily even approximately contemporaneous.

Arguments against this explanation may also be drawn from Nos. 1, 2, 4, and 5. Any explanation must apply to Britain, but the indications of cold conditions in Pliocene times, when the sea reached British shores in East Anglia, Cornwall, and Aberdeen, are inexplicable on this hypothesis. Furthermore, the sea-level was not appreciably lower in Caithness, Aberdeen, the Firth of Clyde, and the Irish Sea at a time when glacial conditions of great severity had set in; and in Yorkshire, when the Scandinavian glacier approached the coast, the land stood at the same level as at present.

The authors formulate no hypothesis, but they consider that the causes are to be sought outside the earth; and, having regard to the uniqueness of the Glacial period, its recency and its very gradual oncoming, they think it may be connected with a secular cooling of the sun. The great development of sun-spots must affect the radiating power of the sun, and the sudden blazing out of *novæ* shows that causes are in operation which are adequate to produce a temporary rejuvenescence of suns.

The authors ask the aid of astronomers and physicists in the solution of one of the unsolved problems of geology.

5. *The Devon and Cornish Granites.* *By* W. A. E. Ussher.

From the relations of the stratified rocks to the granites of Devon and Cornwall there is no obtainable evidence as to the upheaval of the latter.

From evidences of great mechanical disturbance (such as deflections of strike and constrictions of outcrop), and of metamorphism in areas bordering the granites, and from the shapes, relative positions, and internal structure of the granite masses; from the distribution of the Elvans, and from evidences of the production of cleavage in the area prior to the contact metamorphism of the cleaved rocks, it appears that the sites of the Devon and Cornish granite masses were occupied by the granites or pre-existent and subterraneously connected rocks of pre-Devonian age, which had, in a rigid state, exercised an obstructive influence on the north and south movements, and had thereby produced great mechanical effects on the surrounding strata prior to the alteration of the latter.

The contact alteration of the stratified rocks seems to be coeval with the metamorphism of these ancient masses, and the consequent genesis of the granites in their present form during the later stages, or at the close of the Carboniferous epoch. The intrusion of granitoid rocks perhaps accompanied, certainly succeeded, the solidification of the granites, and continued at intervals down to the Permian quartz porphyries. These rocks, called Elvan dykes, approximate, with some few exceptions (notably the north and south Elvan of Watergate Bay), to the general strike produced by the north and south movements, and in some cases, as near Camelford, to the main strike deflections produced by the resistance of granite masses to these movements, but in proceeding from granite to killas they ignore the slight uptilt of the latter on the margin of the granites.

The evidences in favour of the subterranean connection of the Devon and Cornish granites are too strong to be ignored, and this connection annihilates the application of the laccolitic hypothesis advanced by me to account for the relations of the Dartmoor granite, and at the same time contradicts the suggestion of the upheaval of the granites in or through their surroundings.

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6. *Malvern Crystallines.* *By* A. Irving, *D.Sc.*, *F.G.S.*[1]

The author, after ten weeks' field-work upon the Malvern crystallines, has been led, as the result of his observations, to attach a high value to the theoretical speculations of Professor John Phillips, made many years ago, as to the genesis of the rocks for the most part by mineral differentiation from 'one unerupted magma'; but he goes further than Phillips did, and agrees with Dr. Callaway that the whole series (with one doubtful exception) is of 'igneous' origin, though unable to follow that author in recognising a sequence between the diorites and the granites. Reasons for this difference of view are given in the paper.

The really *intrusive rocks* are either (1) felsitic dykes (in places a quartz-porphyry), (2); dykes of basic rock, in many cases some variety of dolerite, though in some perhaps a fine-grained diorite, evidence of their intrusive relation to the granite-diorite series being given in the paper.

The *structural phenomena* presented by the rocks of this crystalline chain the author classes as (i) *Diorite-gneiss*, the primary structure being in some cases rendered somewhat schistose by shearing prior to final consolidation; (ii) *Gneissose* (*flaserig*) *structure*; (iii) *Phyllolithic structures, approaching in various degrees to true schists*, including *hornblende-schists* (due to local excessive deformation of the diorite by accentuation of pressure against the more rigid felspathic masses), *fissile felspathic rocks* (on the cleavage-planes of which secondary mica appears to have been developed at the expense of the felspar), and *sericite-schists* which belong probably to a later stage of development, and resemble rather the younger (Casanna) schists of the Alps; (iv) *Shear-planes*, in which dynamic action appears to have resulted solely in the degradation of the original minerals after pulverisation unaccompanied by any resultant reconstruction of higher silicates; (v) *Crush-*

[1] Published *in extenso* in the *Geological Magazine* for October 1892.

planes, in which either (*a*) breccias, or (*b*) mere fine chloritic débris, rendered crudely fissile in the presence of water by pressure, have resulted from large and small dislocations, to which the mountain-mass has been subjected at various periods of its history.

The author's *general conclusions* are:—

1. That the prevalent petrological morphology of the Malvern crystallines is *diagenetic*, rather than due to subsequent metamorphism.

2. That the geotectonic features, due to the action of purely mechanical forces, are mainly of a *metataxic* nature, and that such forces have been very limited in their action in altering the atomic relationships of the chemical constituents of the rocks.

3. That the most important problem the Malvern crystallines still present to the investigator is the determination of the limits of action of dynamic forces, and of original segregative action by atomic movement (supplemented by the differential action of gravity upon minerals of different density in the primordial magma, aided perhaps by forces of a tidal nature upon the magma as a whole) in bringing about the structural phenomena presented by the Malvern crystallines.

4. These phenomena seem to lend no support to the doctrine of 'regional metamorphism,' as usually understood, for they seem to admit of easier explanation as the results of deformation of originally crystalline masses, rather than of reconstruction out of elastic materials.

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7. *The Igneous Rocks of the Neighbourhood of Builth.* By Henry Woods, *B.A., F.G.S.*

An account of the geology of the Builth district was given by Murchison in the 'Silurian System' (1839), since which date scarcely anything has been written on it. A series of igneous rocks associated with beds of Ordovician age stretches from near the town of Builth to beyond Llandrindod. In this paper the author confined himself to the southern half of this area, giving a preliminary description of the distribution and characters of the rocks met with, namely, diabase, rhyolite, porphyrite, andesite, and ashes.

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8. *Note on a Green Sand in the Lower Greensand, and on a Green Sandstone in Bedfordshire.* By A. C. G. Cameron, *Geological Survey of England and Wales.*

The beds in the section at the 'Parish Sandpit' at Aspley Guise are given below, in descending order.

	Ft.	In.
1. Yellow and grey sand with strings of yellow fullers' earth .	20	0
2. Lenticular seam yellow fullers' earth . . . 6 ft. to	3	0
3. Yellow and grey sand, in parts false-bedded . . .	25	0
4. Yellow fullers' earth, dovetailed amongst green sand . .	2	0
5. Yellow ochre	0	2
6. Bright green sand, 'hearted' darker green	2	6
7. Coarse, buff-coloured irony sand	1	8
Oxford clay		
	54	4

The bright green sand (No. 6), with a darker middle portion, consists of irregular-shaped grains of quartz, stained green; besides which, there are brown grains, the precise nature of which remains for the present undetermined. With the hammer this sand gives a brown streak, the brown grains, which are comparatively soft, being the cause of it. The absence of glauconite is a distinct feature in this sand, that being the usual colouring matter of cretaceous green sands. A darker tint of green pervades the middle portion of the bed, giving it the appearance of being 'hearted,' as the expression goes. Rather over a mile from this place, Mr. Whitaker observed in the tower of Husborne Crawley Church a quan-

tity of green sandstone of a bright colour, and sometimes of a glassy texture, which has been recognised as like some that occurs in the Lower Greensand of Ightham, Kent. It is a serviceable-looking stone, and the brightness of its colour adds beauty to the brown sandstone, of which the edifice is mainly built. The stone seems to be a counterpart of the green sand in the Aspley Section, and similarly colour-hearted. Professor Bonney, on receiving specimens of the Husborne Crawley rock, but speaking from sight only, doubts, however, whether it is the same as the green sand at Aspley. It may be mentioned that pieces of the same rock have been dug up in the roadway half a mile from the church, and a larger boulder-like piece lies by the roadside, on the outskirts of the village green. Adjoining the churchyard is a very old-looking excavation that suggests the spot at which this stone may have been got. Seeing the difficulty of transporting stones in olden times, it is extremely unlikely that the stone came from a distance. Possibly, therefore, there may be some local equivalent of the Lower Greensand of Kent in the Bedfordshire Greensand, which, if not entirely dug away in supplying the stone for Crawley Church, may yet again be brought to light.

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9. *The Fullers' Earth Mining Company at Woburn Sands.* *By* A. C. G. Cameron, *Geological Survey of England and Wales.*

Since reporting to the British Association in 1884 and 1891 on the progress made in working this mineral, the demand for it has gone on steadily increasing, and mining on systematic principles has been established in Bedfordshire for the first time. The mines now show an extensive industry, with underground galleries that extend many hundreds of feet. The layers of earth as they come to be worked are not found disposed quite even, but raised into slight inequalities, ridge-and-furrow-like. Although all one sort of earth, the layers alternate in colour downwards, from yellow, through blue, to yellow again; a difference in colour which Mr. Player, who has analysed the Woburn earth, does not consider is explained by difference in composition.

It has long since been suggested that the name 'Woburn Sands' should be applied to the lower portion of the Lower Greensand of the Midlands, and the name may well be retained for Bedfordshire and Bucks. It is at Woburn Sands, in these counties, that the greatest expanse and greatest thickness of Midland Counties Greensand occurs, and where it contains also those valuable deposits of fullers' earth.

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10. *Report of the Committee on the Circulation of Underground Waters.*
See Reports, p. 264.

FRIDAY, AUGUST 5.

The following Papers were read :—

1. *On a Widespread Radiolarian Chert of Arenig Age from the Southern Uplands of Scotland.* *By* B. N. Peach, *A.R.S.M., F.R.S., F.G.S., of the Geological Survey of Scotland.*

[Communicated by permission of the Director-General.]

The Silurian rocks of the South of Scotland are chiefly made up of greywackes and shales. The Moffat shale group, which lies at their base, consists of finer sediments. Beneath these latter there is a widespread deposit of chert, which is chiefly made up of the remains of radiolarians. This chert zone, where typically developed, is about 100 feet thick, and is divisible into—

An upper sub-zone of dark Lydian-stones and massive grey chert.

A middle sub-zone of green chert.

A lower sub-zone of red and chocolate-coloured chert and jasper.

The chert beds or nodules are separated from each other by the finest sediment, and towards the bottom of the zone by tuff and agglomerate, the latter containing angular fragments of radiolarian chert. The zone reposes on a platform of basic lavas and agglomerates. It is seen on the crests of anticlines over an area of from 2,000 to 3,000 square miles of the northern half of the uplands, and, in all probability, has a much greater extension though hidden under newer sediments.

From the chert Dr. Hinde has described in the 'Ann. Mag. Nat. Hist.' for July, 1890, twenty-three species of radiolaria.

This deposit is regarded by the author as a true radiolarian ooze. When traced from south to north the upper zones become in turn replaced by sediment, thus behaving in the same manner as the Moffat black shales, and indicating that the land whence these sediments proceeded lay to the north of what are now the Southern Uplands.

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2. *On the Contact Metamorphism of the Radiolarian Chert in the Lower Silurian Rocks along the Margin of the Loch Doon Granite.* *By* J. Horne, *F.G.S., of H.M. Geological Survey of Scotland.*

[Communicated by permission of the Director-General.]

While tracing the representatives of the Moffat series in the neighbourhood of Loch Doon, during the present summer, certain remarkable features were noted by me in the radiolarian chert when followed along the outcrop to the point of junction with the granite. About two miles from the igneous mass the chert presents features similar to those in the unaltered areas between Abington and Leadburn. About a mile from the junction the chert becomes slightly granulitic, and the radiolaria are not so discernible with the pocket lens; while the graptolites in the adjoining black shales are quite fresh and determinable. About half a mile from the margin of the granite the chert has been completely granulitised, and yet the radiolaria are still traceable in the matrix. At this stage there is a slight development of mica. Close to the granite the chert has undergone a complete transformation; the rock has been recrystallised, consisting of large quartz grains with irregular edges, remarkable for the number of inclusions. Biotite is largely developed as rounded inclusions in the quartz granules.

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3. *On the 'Grampian Series' (Pre-Cambrian Rocks) of the Central Highlands.* *By* Henry Hicks, *M.D., F.R.S., Sec. of the Geol. Soc.*

In his address to the Geologists' Association in the year 1883 ('Proceedings of the Geologists' Association,' vol. viii. p. 270) the author gave the name of 'Grampian series' to a group of rocks which occupy an extensive area in the Central Highlands. He described them briefly as 'tender gneisses, bright siliceous schists, chiastolite schists, quartzites and limestones,' also some 'chloritic schists.' He classed them as of pre-Cambrian age, and all the evidence since obtained tends to confirm this view. It is quite possible, of course, that newer rocks may be in places entangled amongst them, but the majority of those which he claimed as being of pre-Cambrian age are now generally admitted to be older than any of the Palæozoic rocks of that area. The further descriptions of these rocks now given have been prepared with the kind assistance of Professor T. G. Bonney, D.Sc., F.R.S., to whom the author some time since submitted specimens, collected at various points in the year 1880.

From *Near Ballachulish, &c.* A finely banded, fine-grained micaceous schist, containing apparently a considerable amount of felspathic matter.

From *Glen Spean, &c.* Fine-grained gneisses, not rich in quartz, but with a considerable amount of black mica, not markedly foliated except as the result of subsequent pressure. All are characterised by a peculiar speckled aspect, the spots being about the size of pins' heads. The felspar varies from a warm to a reddish grey.

From *Tyndrum, &c.* A somewhat varying series of schists, but with a common facies. Some have but little mica, consisting mainly of quartz and felspar, and pale grey or reddish in colour; others are very micaceous schists of a lead colour, with sheen surfaces and indications of mineral banding. There are also very quartzose gneisses of a white or pinkish white colour.

Crianlarich and Killin, &c. Calc mica-schists, with sheen surfaces due to subsequent pressure, but showing mineral banding; also fine-grained gneisses like some of those near Tyndrum. But as they have a very marked cleavage foliation they may originally have been somewhat coarser grained. A garnetiferous mica-schist from several places.

Blair Athol, &c. Dark mica schists, with rather a carbonaceous aspect and a very marked cleavage foliation. Some show on close examination along the edges a speckled aspect, recalling some of the gneisses mentioned above. There is also a fairly coarsely crystalline limestone, with specks and streaks of green serpentinous material and some scattered pyrite; also a calc mica-schist modified by pressure and some quartzose schists.

To the south of this line, as mentioned by the author in another paper ('Proceedings of the Geologists' Association,' vol. vii. p. 84), 'schistose and slaty chloritic rocks become more abundant in association with micaceous rocks,' and 'everywhere strongly recall to mind the pre-Cambrian rocks of Wales, especially those in Anglesea and in the Lleyn Promontory.'

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4. *On the Still-possible Cambrian Age of the Torridon Sandstone.* *By* J. F. Blake, *M.A., F.G.S.*

The Torridon Sandstone had been last year removed from the Cambrian on account of the discovery of a species of *Olenellus* in the unconformably overlying series. There is, however, an *à priori* improbability in the rock being pre-Cambrian—amongst which in this country no red grits and conglomerates are known—while this is everywhere the character of the Lower Cambrian, except in particular isolated spots whose peculiarities are due to special conditions, and not to the epoch of the deposits. The main points, however, are that the fauna of the Durness Limestone had been examined by C. D. Walcott, of the United States Geological Survey, and recognised by him as Ordovician, and not Cambrian, by comparison with the American series, and that the species of *Olenellus* discovered in these fucoid beds in Durness was not of the same section of the genus as those which had been definitely found in position below the *Olenus* and *Paradoxides* beds, and might even be separated as a distinct genus. The supposed pre-Cambrian age of the Torridon Sandstone depended therefore only on the supposed limited range of a genus of several sections, which limited range had never been proved.

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5. *On the Alleged Proofs of Submergence in Scotland during the Glacial Epoch.* *By* Dugald Bell, *F.G.S.*

I. *Chapelhall, near Airdrie.*

The maximum degree of submergence in Britain during Glacial times has been the subject of much discussion among geologists. The view held till recently—that it may have been 1,500 feet or more—is now generally abandoned. Minor yet considerable degrees of submergence are still usually admitted—up to 500 or 600 feet—one of the supposed proofs of which is the shelly clay that was found at Chapelhall.

Regarding this deposit little is really known. It was first recorded by Mr. Smith, of Jordanhill, in 1850, from information supplied to him by Mr. Russell, an operative miner, who came upon it at 510 feet above the sea in digging a well. Some shells, curiously enough all of one species, *Tellina calcarea* (*proxima*), had been taken from it, and the clay has not been seen since. Sir A. Geikie, Dr.

Crosskey, and others have made further inquiries, but have obtained very little additional information. The well was built up, and in other wells sunk in the immediate neighbourhood the clay had not been found. At most, it seems to have been a limited strip or patch.

Its very limited extent, the absence of marine organisms in the overlying boulder-clay, and the highly arctic character of the only species of shell known with any certainty to have been found in it appear strong objections to its being considered a true marine bed. On the other hand, there are probabilities, from its position, &c., of its having been transported by land ice. It is submitted that further attempts to find the clay again, and re-examine it, are very desirable.

II. *Clava and other Northern Localities.*

The shelly clay found at Clava, near Inverness, 500 feet above the sea, and described by Mr. James Fraser, C.E. ('Trans. Edin. Geol. Society,' vol. iv.), is thought by some to be a clearer proof of submergence than that which was found at Chapelhall. The shelly sands and gravels, which occur at lower levels in Aberbeenshire, &c., are usually referred to along with it. It occurs under some 45 feet of boulder-clay and 20 feet of stratified sand. Was it laid down by the sea where now found? It seems to be of very limited extent, and the overlying sand and boulder-clay furnish no proof of marine origin, as they contain no organic remains. Thus the difficulties presented by Chapelhall occur here also. On the other hand, it seems equally probable, as in the case of Chapelhall, that the deposit owes its present position to transport by land ice.

The district is one of intense glaciation, and all around it there is evidence of this particular effect, viz., the transport inland of materials from the sea by land ice, *e.g.*, Caithness, along the eastern coast of Aberdeenshire, and near Elgin. In the neighbourhood of Clava there is every proof that the ice issuing from the Great Glen curved gradually round to the eastward, assuming at length, near Forres, an almost due west to east direction. The cause of this was doubtless the ice-blocked condition of the Moray Firth from the numerous great ice-streams pressing into it from the west. There is every likelihood, or rather certainty, that the ice would pass over part of the sea-bed before reaching Clava, and in that case it may have transported shells or shelly clay along with it, as in many other instances. Here, also, to settle the point further examination is desirable.

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6. *On some Calcareous Tufas in Norway.*

By Professor Axel Blytt, *of Christiania.*

In the valley of the Gudbrandsdal, in the central part of Norway (lat. 61° 30′ to 62°), there are found some calcareous tufas which will now be described.

In the upper part of this valley, not far from the Dovrefjeld, at the farm of Leine, in the district Nordre Froen, 500 metres above the sea-level, the following series of strata was found in descending order:—

7. Vegetable earth, 0·10–0·15 m.
6. Greyish-white hard tufa with *Pinus silvestris*, 0·58–0·68 m.
5. Greenish-grey clay without fossils, 0·04 m.
4. Yellowish-grey, partly sandy tufa with *Pinus silvestris*, *Dryas octopetala*, &c., 0·03 m.
3. Yellowish-grey, hard, and slaty tufa with *Betula odorata*, &c. (but neither *Pinus* nor *Dryas*), 0·45 m.
2. Ferruginous clay without fossils, 0·03 m.
1. Boulder clay (glacial).

At the present time the springs which deposited the tufa have almost disappeared, and the tufa deposition has ceased. At the time when the tufas were formed the rainfall must have been much more considerable than it is now, and the springs much more numerous, for at the uppermost spring, which now is

scarcely more than a third of a metre broad, the tufa was found to extend for a breadth of not less than thirty metres.

As shown by the section given above, we find below the vegetable mould a thick stratum of hard tufa, which we will name the fir tufa, and which is all through its thickness quite full of leaves, cones, bark, &c., of the Scotch fir (*Pinus silvestris*). In this bed we also find (but more sparsely) the leaves of *Betula verrucosa* and *B. odorata*, *Populus tremula*, *Salix caprea*, *Vaccinium vitis idæa*, *Mnium punctatum*, *Hypnum falcatum*, &c. The common spruce (*Picea Abies*) grows now plentifully through all the valley, but is quite wanting in the tufas, from which we may conclude that the formation of tufa had ceased before the immigration of the spruce into the Gudbrandsdal.

Below the fir tufa there comes first a clay (5) and then the stratum (4). Both these strata are of inconsiderable thickness. The stratum (4) is a crumbling, calcareous sandy clay, in which are found small lumps of hard tufa. In these we find still some pine leaves, but besides them, in great numbers, the beautiful leaves of *Dryas octopetala*, and (more sparsely) some other arctic plants, as *Salix reticulata* and *S. arbuscula*. I found also in this stratum leaves of what appears to be *Cotoneaster vulgaris*, besides some other plants. In the lower beds (3–1) neither *Pinus*, *Dryas*, *Salix reticulata*, nor *S. arbuscula* is found. We learn from this that *Dryas* and the other arctic plants named flourished at the place when *Pinus silvestris* first immigrated.

The bed (3) is hard and of considerable thickness. Its flora is quite different from that of the strata already described. I name this bed the birch tufa. It has no trace of *Pinus*, but is quite full of the leaves of different foliferous trees and shrubs, as birch (only the mountain birch, *Betula odorata*), *Populus tremula*, *Salix caprea*, *S. glauca*, *Ribes rubrum*, &c. *Betula* and *Populus* occur to the bottom, where also *Hypnum falcatum* and *Equisetum variegatum* are found. There is no arctic flora at the bottom. The clay (2), which rests on the bottom moraine of the old glacier, has no fossils.

In this manner we find at Leine mainly two different beds of tufa. The oldest of the two is the birch tufa, the youngest the fir tufa. Between them there is intercalated a clay and a thin layer of tufa with *Pinus*, *Cotoneaster*, *Dryas*, and other arctic plants.

At the other and southern end of the long valley of Gudbrandsdal, not far from where the river falls into the lake Mjösen, there is another deposit of tufa. This deposit occurs at the farm Nedre Dal, in the district of Faaberg, 225 metres above the sea-level. We find here the same two stages as at Leine, viz., birch tufa and fir tufa, but the intermediate *Dryas* tufa is wanting. In the two beds, which here also occur as separate blocks, we find mainly the same fossils as at Leine. In the birch tufa at Nedre Dal occur *Betula* (only *B. odorata*), *Populus tremula*, *Prunus Padus*, *Salix caprea*, *S. nigricans*, *Myrtillus uliginosa*, *Equisetum hiemale*, &c., and in the fir tufa *Pinus silvestris*, *Betula odorata*, *Vaccinium vitis idæa*, *Linnæa borealis*, &c. At the locality where the tufa occurs, no tufa is formed at the present time. The spruce (*Picea Abies*) and *Acer platanoides* grow abundantly at the place, but both are wanting in the tufas.

Not far from Nedre Dal, at the northern end of the great lake Mjösen, in the district of Birid, I found this summer a third deposit of tufa with the two same separate stages, viz., birch and fir tufa.

From all this we learn that the flora of the Gudbrandsdal (as, indeed, the whole Norwegian flora) immigrated during alternating rainy and dry periods. At first we have a time when glaciers flowed down the valley. After the ice had retired there was first a dry period, when the clay (2) was deposited. Then the rainfall increased again, and the springs formed a bed of tufa with such plants only as still grow in the sub-alpine birch region of our mountain valleys. Then the climate became drier. *Dryas* and other arctic plants descended from the higher mountains and flourished, together with *Cotoneaster*, at the upper limit of the immigrating pine forests, and soon afterwards the formation of tufa ceased totally, and the clay (5) was deposited. Once again the rainfall increased, and a new bed of tufa was formed. During this moist period all the valley was clothed in sombre woods

of the Scotch fir, in which also, besides a number of sub-alpine plants, more southern plants, as *Betula verrucosa*, occurred. At last the climate again became dry, and the formation of tufa ceased anew. After that time *Picea Abies*, *Acer platanoides*, and other plants of a more southern type immigrated into the valley.[1]

In the case of these tufas there is no doubt that the alternation of tufa beds and clays is due to a climatic period of long duration (probably caused by the precession of the equinoxes). In a paper, On Variations of Climate in the Course of Time ('Nature,' 1886), I have given many reasons for the occurrence of such a period. And in a later paper, On the Probable Cause of the Displacement of Shore-lines (London, Edinburgh, and Dublin, 'Phil. Mag.,' 1889, pp. 405, 487, reprinted in the 'Smithsonian Report,' Washington, 1890, p. 325), I have tried to show how, with the aid of alternating strata, we may possibly get to a computation of geological time. It is no objection to this theory that alternating strata may be formed also by other and more local causes. We should try to learn to distinguish between such local alternations and those which are caused by more generally operating and probably cosmical causes.

Lastly, I would remark that in Denmark and Southern Norway the alternating layers of forest and peat in peat bogs show more alternations than the tufas and peat of our mountain valleys, the reason being probably that glaciers lingered in the mountain valleys a long time after the lowlands had been free of ice and snow.

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7. *Fossil Arctic Plants found near Edinburgh.*

By CLEMENT REID, *F.L.S.*, *F.G.S.*

Recent discoveries by Mr. Bennie, of the Geological Survey, have brought to light a series of silted-up tarns or small lochs in the neighbourhood of Edinburgh. These tarns seem to have lain in irregular hollows left on the retreat of the ice, for the lowest deposits usually yield remains of arctic plants. The principal localities for these plants are Corstorphine and Hailes. Trees, except perhaps the alder, are entirely missing in the lower deposits, and the vegetation consists mainly of dwarf willow and birch, with a few herbaceous plants, of species still living within the Arctic Circle. The list now includes the following plants, those marked with an asterisk being arctic species no longer living in the lowlands of Scotland:—

Flowering Plants.

Ranunculus aquatilis, Linn.
„ repens, Linn.
Viola (?).
Stellaria media, Cyr.
Rubus sp.
*Dryas octopetala, Linn.
Potentilla sp.
Poterium sp.
Hippuris vulgaris, Linn.
Myriophyllum spicatum, Linn.
Taraxacum officinale, Web.
Andromeda polyfolia, Linn.
Menyanthes trifoliata, Linn.
*Oxyria digyna, Hill.
*Betula nana, Linn.
Alnus (?).
Salix repens, Linn.
* „ herbacea, Linn.
* „ polaris, Wahlb.
* „ reticulata, Linn.
Empetrum nigrum, Linn.
Potamogeton sp.
Eleocharis palustris, R. Br.
Scirpus pauciflorus, Lightf.
„ lacustris, Linn.
Carex, 2 sp.

Mosses (*determined by* ANTONY GEPP, *F.L.S.*).

Barbula fallax, Hedwig.
* „ fragilis, Bruch & Sch.
Grimmia sp.
Racomitrium sp.
Philonotis fontana, Brid.
Aulacomnion palustre, Schw.
Webera sp.
Bryum sp.

[1] A fuller description of these tufas is given in Engler's *Botanische Jahrbücher* for this year.

Pogonatum sp.
Polytrichum sp.
Camptothecium nitens, Schimp.
Hypnum polygamum, Schimp.
„ fluitans, Linn.
„ revolvens, Swartz.
Hypnum rugosum, Ehrh.
„ cupressiforme, Linn.
* „ sarmentosum, Wahl.
„ cuspidatum, Linn.
* „ trifarium, Web. & Mohr.
„ scorpioides, Linn.

8. *The Cuttings on the Crieff and Comrie Railway.*

By Henry Coates, *F.R.S.E.*

As the Crieff and Comrie Railway is now being rapidly completed, the cuttings will in a very short time be covered or obscured. A record of what they presented when fresh may therefore be useful.

The line is a fraction under six miles in length, and runs almost due east and west. Half-way between Crieff and Comrie it passes over the line of the great fault, which approximately divides the Old Red Sandstone of the Midland valley of Scotland from the Crystalline Rocks of the Highlands. The eastern or Crieff section passes over the Old Red Sandstone area, and the western or Comrie section passes over the Highland area. All the cuttings, of which there are seven, occur in the former section.

The first cutting, which is also the most complicated in its geological features, occurs in the village of Crieff. A few yards to the west of King Street the following series was exposed:—At the base, 8 feet of fine yellow sand or silt; next, a bed of boulder clay, 1½ feet thick, in which the boulders are very large and numerous; then 8½ feet of peat, in which are some thin layers of sand and grit; and, on the top of all, a foot of surface soil. This bed of peat is quite local, occupying a shallow basin in the boulder clay. About a hundred yards westwards, in the same cutting, the Old Red Conglomerate rises up in a buttress-like mass, and forms the base of the series at that point. It dips south-east at an angle of 30°. Its upper surface is very much disintegrated, apparently by ice action. Resting on this disintegrated surface is a bed of boulder clay, which to the west of Burrel Street rises until it reaches a thickness of 24 feet. On the western face of this bank of boulder clay there is a bed of river material.

On either side of the valley of the Turret—which the line crosses—there are cuttings through the highest river terraces. In these cuttings boulder clay is exposed at the base for a depth of 3 or 4 feet, on the top of which rests a series of river deposits. These latter consist of fine and coarse gravels, grits, sands, and silts, all more or less distinctly bedded, the finer material frequently exhibiting false bedding. In the boulder clay some of the boulders are very large and finely striated.

Two miles west from Crieff the line passes through a cutting where the Old Red Sandstone is exposed tilted up in a perfectly vertical position, and, indeed, bending over to a reverse angle of 78°. On the truncated edges of these beds rests a deposit of boulder clay, 30 feet thick, and on the top of that 4 or 5 feet of fine sand, apparently of river origin.

The last cutting occurs three miles from Crieff, where the line is carried in a tunnel through the hill on which the Baird Monument stands. The rock through which the tunnel is bored is a very hard and coarse (Old Red) conglomerate.

I am indebted to Mr. John Young, C.E., Perth, the chief engineer, and to Mr. Moncur, the resident engineer, who gave me facilities for inspecting the cuttings, and also placed at my disposal the plans and sections of the line.

SATURDAY, AUGUST 6.

The following Papers and Reports were read :—

1. *On the Physical Geology of Arabia Petræa and Palestine.* *By* Professor Edward Hull, *LL.D., F.R.S., F.G.S.*

The author in this paper stated the results of the observations made during the expedition sent out by the Committee of the Palestine Exploration Fund in 1883-84, including the observations of previous travellers.

After describing the physical features of the region traversed, the author described the Archæan rocks of the Sinaitic and Edomite Mountains, succeeded by the Lower Carboniferous sandstone and limestone of Wady Nasb ; succeeded by the Nubian sandstone (Neocomian or Cenomanian), the Cretaceous and Nummulite limestones, which form the table-land of Palestine and of Arabia Deserta.

The relations of the Pliocene terraces along the coast, and those of the Jordan-Arabah Valley, to the older formations were also discussed.

The author concluded by describing the line of the great fault or system of faults along the line of the Jordan-Arabah Valley, and showed how this great depression had (probably during the Pluvial period) been the basin of a lake, about 200 miles in length, during the period of highest level, and had extended from the Wady-el-Arabah to the Lake of Merom. Conclusions regarding the climatic conditions of the Pluvial period and the extent of aqueous erosion were stated.

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2. *On Two Tunnel Sections in the Cambrian of Carnarvonshire.* *By* J. F. Blake, *M.A., F.G.S.*

A section in the Penrhyn Slate Quarries, lately made, shows felsite, like that of Llyn Padarn, in the midst of purple and other slates ; a position consistent with intrusion or contemporaneity, but not with a pre-Cambrian age of the felsite, except by the aid of hypothetical faults.

The already described adit in Moel Tryfaen had been examined, and a conglomerate, similar to that of the summit, but only thirty inches thick, had been found between the purple and banded slates. This is considered to be probably different from the more massive and wider spread mass on the summit, though no proof of this is as yet offered. The conglomerate, however, is not at the base of the series in any case, but is followed below by a long series of banded slates, Bangor breccia, coarse grits, and a lower smaller breccia conglomerate. Amongst the grits are two bands of felsite, possibly intrusive, but certainly not earlier than the grits, so that the hill has, on the whole, very little felsite in it at all.

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3. *Report of the Committee on the Volcanic Phenomena of Vesuvius.* See Reports, p. 338.

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4. *Report of the Committee on Elbolton Cave.*—See Reports, p. 266.

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5. *Interim Report of the Committee on the Excavations at Oldbury Hill.*

MONDAY, AUGUST 8.

The President's Address (*see* p. 695) was delivered, and the following Papers were read:—

1. *On the Relation of the Bunter Pebbles of the English Midlands to those in the Old Red Sandstone Conglomerates of Scotland.* *By* Professor T. G. Bonney, *D.Sc., F.R.S.*

The author had recently examined the conglomerates near Brodick (Arran), at Rothesay, and in the neighbourhood of Callander. He had already expressed the opinion that the quartzites in the Midland Bunter Pebble Beds were identical with those abundant in Arran, and was convinced this was the case. The felstone pebbles found in the Midlands were, he was now satisfied, similar to the Scotch felstones, which occur both *in situ* and as pebbles in the Old Red Sandstone conglomerates, and in more than one locality in the latter he had found a peculiar quartz-felspar grit (like Torridon Sandstone), which occurs also in the Midland Pebble Beds.

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2. *On the Relations of the Rocks of the Lizard District.* *By* Alex. Somervail.

These rocks include the hornblende-schist, serpentine, gabbro, granite, &c., which the author regards as all belonging to the same period of geological time, and to have segregated or separated out from each other during the cooling of a homogeneous magma.

There seems absolute evidence in the field to show that the serpentine is a non-intrusive rock, that it was the first portion of the magma to cool, and is broken through by all the other rocks, but that it is intrusive into none.

The relations between the serpentine and the diorite and portions of the granulitic rocks are those of segregation, and not of intrusion, as many sections show these rocks associated together in great alternating bands with a concentric-like structure with complete transition varieties, but with no signs of intrusion on the part of either. These concentric-like structures, which are certainly original—due to cooling—have been subsequently displaced and broken up, so that the now isolated portions are mistaken for intrusive tongues of serpentine or included fragments of hornblende. When followed out they resolve themselves into what were once connected masses.

While the main masses of these rocks have separated out from each other, and cooled in the order of increasing acidity, there also seems absolute proof in the field that the intrusive dykes in the serpentine, consisting of diorite, granite, complexes of these and also of gabbro, are but portions of the uncooled magma of the main masses which were able to penetrate the serpentine.

That the main masses and the dykes are of one and the same age is evident, not only from their mineral composition and lithological aspect, but also from the fact that all these rocks are inter-related—for example, the gabbro and diorite dykes coalesce, and dykes of the former have margins of the latter. The diorite contains inclusions of gabbro, and in some instances inclusions of the latter contain others of the former. The granulitic rocks, diorite, and gabbro occur as a regular interbanded series, and there are also schists of these complexes.

The facts seem to warrant the following conclusions:—

1. That all these rocks belong to one geological epoch; that their relations are principally those of segregation or separation, and in a lesser degree of contemporaneous intrusion on the part of the less basic and more acid portions of the magma.

2. That the olivine portion of the magma now forming the serpentine was the first to cool, followed by the others in the order of their increasing acidity.

3. That the serpentine is a non-intrusive rock, and one into which all the other types of rock have been intruded, the granite intrusions being the latest.

3. *The Ice-Shed in the North-West Highlands during the Maximum Glaciation.* *By* B. N. Peach, *F.R.S.*, *F.G.S.*, *and* J. Horne, *F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

In the course of the geological survey of the North-west Highlands certain data have been observed which seem to point to the conclusion that during the maximum glaciation the ice-shed did not coincide with the existing water-shed of the region. From an examination of the striæ and the distribution of the boulders, it would appear that the ice-parting then lay to the east of the present water-shed. In the group of mountains forming the eastern chain of Assynt, Sutherlandshire, extending from Glasven and Ben Uidh by Coniveall to Braebag, the phenomena relating to this remarkable dispersion of the ice may be seen to advantage. On Ben Fuaran, which is composed of displaced members of the Cambrian formation (quartzites, fucoid beds, and serpulite grit), boulders of Lewisian gneiss are met with, which have been borne westwards from the deep corries on the north-east slope of the Ben More range. In like manner on the long ridge of Braebag, running southwards from the Beallach of Coniveall, the average height of which is over 2,000 feet, splendid striated surfaces are observable, the ice-markings pointing in a westerly direction. Numerous blocks of thrust Lewisian gneiss and granulitic quartz-schist (Moine schist) occur on the crest and slopes of this ridge, derived from areas lying to the east of Braebag. The average level of the plateau formed by the eastern schists to the east of Kinloch Ailsh is lower than that of the water-shed south of the Beallach of Coniveall.

Passing southwards to the mountainous region in Ross-shire, in the neighbourhood of Kinlochewe, Loch Maree, there is abundant evidence of the granulitic Moine schists having been carried to higher levels by the westerly movement of the ice. On the elevated peaks and slopes of Sgurr Ban, Corrie Mac Fearchar, Ben Slioch, and Ben Eighe, composed of Torridon sandstone and Cambrian strata, numerous blocks of various types of the eastern schists have been observed.

It would appear that during the great extension of the ice, even these lofty mountains had been overstopped by the ice-sheet, while at a later period the various mountain groups formed independent centres for the dispersion of local glaciers.

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4. *On a Bone Cave in the Cambrian Limestone in Assynt, Sutherlandshire.* *By* B. N. Peach, *F.R.S.*, *F.G.S.*, *and* J. Horne, *F.G.S.*

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The authors called attention to a group of caves occurring on the south side of the valley of Allt an Uamh (Burn of the Caves) traversing the limestone plateau of Inchnadamff, Sutherlandshire. Owing to the limestones being piled together by reversed faults, the streams flowing on to the plateau from the surrounding less pervious rocks plunge underground on reaching the limestone and emerge at lower levels. All the tributaries of the Allt an Uamh, save during heavy floods, disappear at a considerable distance above the caves, and issue as two powerful springs about a mile below the bone cave. The authors are of opinion that a stream may have issued from the floor of the bone cave at a time when the valley was filled with glacial deposits up to the level of the caves. These materials having been largely removed by denudation, the water circulates at lower levels in the limestone plateau.

In the autumn of 1889 the authors, together with the Rev. Mr. Short and Mr. Clarence Fry, explored the most easterly cave with the following results, the materials being carefully examined as they were removed:—

(*a*) Peaty matter from a few inches to a foot thick.

(*b*) Lenticular layer of calcareous marl about one foot thick, composed of the remains of various land shells.

(*c*) Red clay or cave earth from one to three feet. Indications of human occupation occur at various levels in the form of layers of charcoal, split and calcined bones, comprising reindeer, red deer, badger, fox, bones of birds—chiefly of grouse—with nests of frog bones.

(*d*) Fine grey clay with quartzite boulders about six inches thick.

(*e*) A layer composed of limestone fragments yielding bones of birds, fish, and *a finely preserved canine tooth of the brown bear*, discovered by Mr. Clarence Fry.

(*f*) A layer of gravel composed of stones foreign to the cave, but occurring in the surrounding drift or derived from rock *in situ* within the basin of Allt an Uamh.

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5. *Interim Report of the Committee for Investigating the Structure of a Coral Reef.*

TUESDAY, AUGUST 9.

The following Papers and Reports were read:—

1. *Landslips in the St. Cassian Strata of S. Tyrol.*
By Miss M. M. Ogilvie.

This paper deals with the nature of the landslips in the Wengen and Cassian strata, in the neighbourhood of St. Cassian in S. Tyrol, and the effect which they have produced in mingling the fossils derived from rocks of different horizons.

The peculiar liability of these strata to landslips is attributable (1) to their lithological character and stratigraphical relations; they are soft, easily weathered, earthy tuffs and thin-bedded marls and limestones, while the strata above and below them are composed of much harder rock, dolomitic or volcanic; (2) to their occurrence at the high altitude of 5,000 to 7,000 feet, and in a region where the ordinary atmospheric agencies may, and often do, indirectly produce most violent effects, due to the sudden swelling of mountain streams and their increased powers of eroding and transporting loose or insecure material.

If, from any cause whatever, a breach takes origin in a high-lying meadow, either suddenly or gradually, it must inevitably become wider and deeper in the course of years. The essential features in the development of the landslips in Wengen and Cassian strata are admirably illustrated by the actual exposures on the Alp of Prelongei above St. Cassian. The turfed ground along the top terrace or ridge is cracked, fissured, and rent into huge irregular 'clods,' which sink in larger or smaller fragments steadily downward and outward; the streams at the base of this ridge eat backward and undermine fresh portions, at the same time actively carrying off the débris and layering it afresh at lower levels.

The 'Muren,' on the S. side of Prelongei, are great scars, 300 feet high, which were opened up by a series of landslips three centuries ago. As the dip of the beds is to the N.E., these 'Muren' have remained steep, whereas in the case of slips on the N. side, the slipped rock rests as it were on a sliding plane, and must travel slowly downward. The loosened material from each new slip fills up the gap made by the previous slip; the surface thus becomes raised, and a plane of repose is gradually reached.

Several highly fossiliferous limestones and marls occur in the Cassian beds; some in the upper horizons capping the series exposed in the 'Muren' have yielded most of the fossils gathered over the whole Prelongei and Stuores Alps. For fragments of these fossiliferous beds occur in secondary position in the lower ground where the remains of successive landslips form in some parts an almost continuous mantle over the beds actually in position.

A lower fossiliferous zone is recognisable at the base of the beds of the 'Muren,' but its precise palæontological value will take some years to determine. To this end the fossils lying loose cannot be used; only those which have been so far weathered out in the bedded rock itself can be regarded as secure evidence. This whole series, in which the landslips here and elsewhere have mainly taken place, merit from the fossils contained in them the name of St. Cassian strata, but they

are essentially the upward continuation of the Wengen beds, the two series together forming a sharply defined complex of very great tektonic importance in the region of 'The Dolomites.'

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2. *On a Granite Junction in Mull.*

By J. G. Goodchild, *H.M. Geological Survey.*

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A quarter of a century back Professor Hughes expressed the opinion that granites and some other intrusive rocks did not thrust aside the rocks they invaded, but rather that they occupied exactly the same position, and that they replaced, rather than displaced, an equivalent bulk of the rocks into which they had eaten their way. At a later date Mr. Clough came to the same conclusion in regard to Whin Sill of Teesdale. The idea did not find acceptance except amongst field geologists, the chief objection urged against it being the remarkable uniformity of composition of the invader where the rocks assimilated happened to present a wide range of chemical composition. Mr. Clough suggested as an explanation of this difficulty that the molten rock might have undergone circulation throughout the mass as fast as it was melted up.

The author's examination of the peripheral parts of the Ross of Mull granite (as well as of others in Cornwall and elsewhere) seemed to him to lend further support to the views advanced by Professor Hughes and Mr. Clough. He considers that the evidence is in favour of replacement by melting in the case of the majority of intrusive masses, the molten rock being diffused as an alloy throughout the mass, but that where the superincumbent pressure was comparatively low he admits that a true laccolite might really be formed, and the molten mass thrust into a space formed by local upheaval of the overlying rock without any such replacement.

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3. *The St. Bees Sandstone and its Associated Rocks.*

By J. G. Goodchild, *H.M. Geological Survey.*

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The author reviews the history of opinion upon the classification of the New Red rocks of Cumberland and Westmorland, and then gives the following as the maximum thickness, general succession, and probable equivalents elsewhere of these rocks:—

New Red Series (Upper Division).

	Maximum observed thickness in feet.
(5) Red marls with rock salt and gypsum	950
(4) St. Bees Sandstone, with the following subdivisions:—	
(*d*) Waterstones; (*c*) zone of tile red phases; (*b*) dull Red Sandstone with local bands of fine conglomerate and occasional pebbles; (*a*) zone of variegated sandstones. In all	2,000
(4*d*) graduates downward into—	
(3) Gypsiferous marls with local conglomerate at its base	300

Magnesian Limestone Group.

(2″) Magnesian Limestone	25
(2′) Plant beds	150

Lower New Red.

(1) Penrith Sandstone: the Brockrams	1,500

Extensive Unconformity.

There is a perfectly unbroken downward succession as far as the conglomerate at the base of (3); and, therefore, as (4*c*) is admitted on all hands to be of Triassic

age, the remainder of (4) and the whole of (3) must be of Triassic age also. (3) lies indifferently upon either member of (2) or upon the upper part of (1). It is therefore slightly unconformable to the beds below. These are admitted on all hands to be Permian; therefore the break between the Trias and the Permian is at the base of (3). The author considers that the whole of these rocks form the natural basement beds of the Neozoic rocks, and that the dividing line between the Palæozoic rocks and those of Neozoic age should be taken somewhere between the Red rocks of the Salopian type (to which he would restrict the term Permian) and the true New Red, as the term is here employed. He considers that the New Red proper bears the same relation to the Jurassic and Rhætic rocks that the upper Old Red Sandstone does to the Carboniferous, and that the Salopian Permian may possibly occupy the same relation in regard to the Carboniferous rocks as the Glengariff Grits do to the Silurians. Some at least of the Salopian rocks may be simply Carboniferous rocks stained by infiltration from the New Red.

The author regards the St. Bees Sandstone as mainly equivalent to the Bunter, and proposes that the term Bunter Marls should be applied to the marls which here (and in Devonshire, &c.) occur at the base of that subdivision.

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4. *The Sequence of Gneissose Rocks.* *By* J. J. H. Teall, *F.R.S.*, *F.G.S.*

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5. *Supposed Radiolarian Remains from the Slates of Howth.* *By* Professor W. J. Sollas, *F.R.S.*, *F.G.S.*

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6. *Supposed Radiolarian Remains from the Culdaff Limestone.* *By* Professor W. J. Sollas, *F.R.S.*, *F.G.S.*

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7. *On some Dicynodont and other Reptile Remains from the Elgin Sandstone.* *By* E. T. Newton, *F.G.S.*, *F.Z.S.*

At the Aberdeen meeting of the British Association in 1885 Dr. Traquair called attention to the skull of a dicynodont which had been discovered in the Elgin Sandstone of Cutties' Hillock (= New Spynie). Since that time several other specimens have been obtained from the same place, some of which are the property of the Elgin Museum, while others belong to the Geological Survey of the United Kingdom. These specimens are now being worked out by the author, and this communication is a preliminary note on the interesting results which have been obtained.

All the reptile remains obtained from Cutties' Hillock are in the condition of hollow casts, the bones themselves having been dissolved away; this, it will be remembered, was the case with some of the examples of *Stagonolepis* from the Elgin Sandstone, described by Prof. Huxley, and the method of taking casts from the hollow cavities, which was adopted in that case, has been found of great advantage in the present instance. The blocks when brought from the quarry were more or less split open, exposing portions of the specimens. In some cases these cavities were traced out and developed with the chisel, while in others they were farther split open, thus allowing casts to be taken. In many cases these casts had to be made in several parts and afterwards fitted together. The time and labour involved in this task have been repaid by the restoration of the skulls and parts of skeletons of several *Dicynodonts* and one or two other equally remarkable forms of reptiles.

In most of these specimens, including that noticed by Dr. Traquair, the skulls are similar in form, although differing in minor details, and have a general resemblance to the South African *Dicynodon* and *Oudenodon*, some of them having small tusks in the maxillary bones. With most of these skulls parts of the skeleton have

been found. Two or three show the position of the vertebral column and ribs, but up to the present no definite centra have been traced; besides this there is evidence of scapula, clavicle, humerus, radius, and ulna, the humerus having the characteristic anomodont expansion of the two extremities. In two specimens the ilia are preserved. These forms appear to be distinct from *Dicynodon*, and probably represent at least two or three species.

Another skull presents most of the characters of *Ptychognathus*, but has a short muzzle and no teeth. The last and by far the most remarkable skull of this series is about six inches in length, and has the outer surface completely covered in by bony plates, the nostrils, orbits, and pineal fossa being the only apertures. The chief feature of this skull is the extreme development of horns upon the face and cheeks, there being about thirty of these formidable defences, varying from a fourth of an inch to nearly three inches in length, besides some smaller bosses. The dentition is pleurodont, and resembles very closely that of the living *Iguana*; the palate is lacertilian, but with the pterygoids united in front of the pterygoid vacuity. This skull reminds one very strongly of the living *Moloch* and *Phrynosoma*, but it probably finds its nearest ally in the *Pareiasaurus* from the South African Karoo Bed. The detailed description of these specimens is nearly completed, and will, it is hoped, be shortly published.

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8. *Report of the Committee on the Registration of Type Specimens.*
See Reports, p. 289.

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9. *Report of the Committee on the Cretaceous Polyzoa.*
See Reports, p. 301.

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10. *Report of the Committee on Earth-tremors.*—See Reports, p. 343.

WEDNESDAY, AUGUST 10.

The following Papers and Reports were read:—

1. *Additions to the Eurypterid Fauna of the Upper Silurian.*
By MALCOLM LAURIE, *B.A., B.Sc., F.L.S.*[1]

The uppermost Silurian rocks are almost universally characterised by a well-developed Eurypterid fauna. It has been described in Russia, Bohemia, and America, as well as in two or three places in Great Britain. The range of the species, however, is, as a rule, very limited, almost every new locality yielding new forms.

The Silurian rocks of the Pentland Hills, passing as they do conformably into the Lower Old Red sandstone, might be expected to yield some trace of this fauna, and a small bed containing somewhat abundant remains was described by Mr. Henderson in the 'Transactions of the Edinburgh Geological Society,' vol. iii. The collection which he made is now in the Museum of Science and Art, where I had an opportunity of examining it last year.

The specimens belong to three genera, one of which is new. Eurypterus is represented by three species, one of which—represented only by fragments—may be identical with *E. scorpioides* of Woodward; the other two appear to be new.

[1] A detailed account of these forms is in course of publication in the *Transactions of the Royal Society of Edinburgh*.

One, *E. conicus*, is characterised by the conical form of the body and the very large eyes, which are nearer the margin than is usual in Eurypterus. In the other species (*E. cyclophthalmus*), which is only represented by a single specimen, two inches in length, the eyes are circular and comparatively large, the carapace being semicircular and with a distinct border.

Stylonurus is represented by two species, also new. *S. ornatus* is a comparatively large form, about 18 inches in length, and is characterised by the form of the carapace, which is horse-shoe-shaped, the possession of epimera on the posterior segments and the abundance and variety of the ornamentation. The second species—*Stylonurus macrophthalmus*—is much smaller, and the most marked feature is the size of the eyes, which are half as long as the carapace.

The third genus represented is a new one, to which I have given the name Drepanopterus. The carapace in this form is somewhat of the same shape as in Stylonurus, but broader in propotion to its length, measuring 3 inches by 1⅝. The body is short and conical, being widest at the third segment. The first segment seems very much reduced. The ornamentation on the body is reticulate rather than scale-like. Only one limb is preserved, which is 4 inches long and shows the four last joints, of which the first three are subcylindrical and somewhat hour-glass-shaped, decreasing in length from the first to the third. The terminal joint is an inch long, expanded and falcate in shape, the posterior margin being slightly concave and the anterior margin strongly convex. The whole limb is covered with punctate markings. There are traces of a second limb, which probably equalled this one in size. The form of the limb seems to be somewhat intermediate between Stylonurus and Eurypterus.

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2. *Report of the Committee on Fossil Phyllopoda.*—See Reports, p. 298.

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3. *On the Occurrence of* Chonetes Pratti, *Davidson, in the Carboniferous Rocks of Western Australia. By* R. Bullen Newton, *F.G.S., British Museum (Natural History).*

In this communication the author directed attention to some valves of a *Chonetes* recently discovered by Mr. Harry Page Woodward, F.G.S., in rocks of Carboniferous age situated in the Irwin River District of Western Australia, which he referred to *C. Pratti*, a species described and figured by the late Dr. Thomas Davidson in the 'Geologist' for 1859, plate 4, figs. 9–12, p. 116. As the original description, contained only in the explanation of the plates, is necessarily somewhat brief and imperfect, the following additional characters were submitted:—(1) That the external surface of both valves, besides being ornamented with very fine radiating striæ, possess subimbricating concentric lines of growth; (2) that the extent of the cardinal margin represents the minimum width of the shell; (3) that the granular asperities on the interiors of the valves are disposed in lines as they reach the margins, having more or less an elongate appearance resembling short tubular spines; (4) that the external surface of the ventral valve exhibits a number of small orifices placed at irregular distances, which are probably basal attachments of spines, a character known to exist in *Chonetes papilionacea*, *C. Hardrensis*, &c. The author then gave the dimensions of the Davidson type valves, together with those of the Western Australian specimens, the latter being somewhat larger. A minute examination of the Western Australian specimens and their comparison with the originals of *C. Pratti* in the Davidson collection at the British Museum has demonstrated the fact that they are mineralogically as well as structurally the same brachiopod. This fact is of considerable importance, as the Davidson specimens at the time of description were unlocalised, and the species, as far as can be ascertained, has never been referred to since either by Davidson himself or by any other writer up to the present time. There is very little doubt that the Irwin River District, besides producing this new material, yielded also the Davidson

types. The paper concluded with a small list of Carboniferous fossils collected in the same neighbourhood, which have been described and figured by Messrs. A. H. Foord and G. J. Hinde in the 'Geological Magazine' for 1890.

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4. *On Porphyritic Quartz in Basic Igneous Rocks.* *By* Alfred Harker, *M.A., F.G.S.*[1]

Basalts enclosing quartz-grains are known from the Tertiary volcanic areas of the United States and from other parts of the world, and similar grains of quartz occur widely, though sparingly, in the lamprophyre dykes ('mica-traps,' &c.) of the North of England and other districts. Having regard chiefly to the latter group of rocks, the author maintains that the quartz has not the characters of mechanically derived fragments; while it is difficult, on the other hand, to conceive of free silica crystallising from a basic magma. He supposes, as the source of the rocks in question, a large magma-basin separated by gravity into layers of different density. The quartz crystallised out in the upper acid magma, and sank, owing to its superior density, into the lower basic portion, which was afterwards separately injected or ejected as a basic rock.

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5. *On the Occurrence of Pisolitic Tuff in the Pentlands.* *By* H. J. Johnston-Lavis, *M.D., Bac.-ès-Sci., F.G.S.*

During the Saturday's excursion of the British Association to the Pentland Hills, under the able guidance of Mr. Peach, we were shown some tuffs that cap the ridge we were crossing from Logan Burn to Penicuik, or more correctly in the third quarry down from the crest of the ridge between Carnethy and Scald Law. These tuffs overlie scoriaceous andesites, which in their turn are superposed on basalts.

The tuffs are well stratified, at times finely banded, and altogether composed of minute fragments, which in considerable part can be seen to be pumice.

The interesting points about these tuffs, from a vulcanological point of view, is the presence of pisolites, showing all the characters of those structures so common in dusty tuffs of recent formation—that is to say, with a coarse-grained nucleus surrounded by a fine-grained shell.

I originally believed these pisolites to be due to a sort of accretion, such as forms in glazing pottery. They have, however, been shown to be produced by drops of rain falling through a dusty atmosphere. Now such an origin will explain their structure—the rain drop will at first catch both coarse and fine particles on its surface, but preferably the larger ones, for they are more easily wetted. As the drops of water get gradually filled with solid particles the amount of available moisture on the surface gets less and less, so that finally only the finest powder can adhere. Pisolites frequently enclose a cavity in their centre, probably due to the larger particles jamming together and forming a spherical vault around the central drop of water.

The deductions to be drawn from the existence of these pisolites is that they indicate that practically sub-aerial volcanoes, or at any rate vents in very shallow water, are necessary for their production.

I have recognised pisolites in tuffs of Triassic age in Germany, but these of the Old Red Sandstone period are the oldest recorded occurrence of such accretions, and form another link of evidence in favour of the similarity between ancient and actual volcanic action.

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[1] Published *in extenso* in the *Geological Magazine*, 1892.

6. *On Some Limerick Traps.* *By* W. W. Watts, *M.A., F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

After referring to previous descriptions of these Carboniferous volcanic rocks by Messrs. Hull and Kinahan the writer gave a short account of their succession and mineral characters. The earliest eruptions were of porphyrite lava and ash, followed after an interval of sedimentation by eruptions of basaltic lava and ash. Intrusive masses of porphyrite and quartz-porphyrite penetrate the Old Red Sandstone, Carboniferous Limestone, and the eruptive masses themselves. The latest lava in the area is a limburgite containing large crystals of augite and pseudomorphs of olivine in a fine-grained base consisting of augite and magnetite.

SECTION D.—BIOLOGY.

PRESIDENT OF THE SECTION—Professor W. RUTHERFORD, M.D., F.R.S., F.R.S.E.

THURSDAY, AUGUST 4.

The PRESIDENT delivered the following Address:—

AT the meeting of this Association held at Birmingham in 1886 I had the honour of delivering a lecture on the sense of hearing, in which I criticised the current theory of tone-sensation, and I propose on this occasion to discuss the current theories regarding our sense of colour.

I may premise that our conceptions of the outer world are entirely founded on the experience gathered from our sensory impressions. Through our organs of sensation, mechanical, chemical, and radiant energies impress our consciousness. The manner in which the physical agents stimulate the peripheral sense-organs, the nature of the movement transmitted through our nerves to the centres for sensation in the brain, the manner in which different qualities of sensation are there produced—all these are problems of endless interest to the physiologist and psychologist.

Every physiologist has acknowledged the profound significance of Johannes Müller's law of the specific energies—or, as we should rather say, the specific activities of the sense-organs. To those unfamiliar with it I may explain it by saying that if a motor nerve be stimulated, the obvious result is muscular movement; it matters not by what form of energy the nerve is stimulated—it may be by electricity or heat, by a mechanical pinch or a chemical stimulus—the specific result is muscular contraction. In like manner, when the nerve of sight is stimulated—it may be by light falling on the retina, or by electricity, or mechanical pressure, or by cutting the nerve—the invariable result is a luminous sensation, because the impression is transmitted to cells in the centre for vision in the brain, whose specific function is to produce a sense of light.

The same principle applies to the other sensory centres; when thrown into activity, they each produce a special kind of sensation. The sun's rays falling on the skin induce a sense of heat, but falling on the eye, they induce a sense of light. In both cases, the physical agent is the same; the difference of result arises from specific differences of function in the brain centres concerned in thermal and visual sense. We have no conception how it is that different kinds of sensation arise from molecular movements in the different groups of sensory cells; we are as ignorant of that as we are of the nature of consciousness itself.

The subject I propose to discuss on this occasion is not the cause of the different *kinds* of sensation proper to the different sense-organs, but the causes of some *qualities* of sensation producible through one and the same sense-organ.

The theory of tone-sensation proposed by Helmholtz is, that the ear contains an elaborate series of nerve terminals capable of responding to tones varying in pitch from sixteen vibrations to upwards of 40,000 vibrations per second, and that at least one different fibre in the auditory nerve, and at least one different cell in the centre

for hearing, is affected by each tone of perceptibly different pitch. Although the physical difference between high and low tones is simply a difference in frequency of the sound waves, that is not supposed by Helmholtz to be the cause of the different sensations of pitch. According to his theory, the function of frequency of vibration is simply to excite by sympathy different nerve terminals in the ear. The molecular movement in all the nerve fibres is supposed to be identical, and the different sensations of pitch are ascribed to a highly specialised condition of cells in the hearing centre, whereby each cell, so to speak, produces the sensation of a tone of definite pitch, which in no way depends on the frequency of incoming nerve impulses, but simply on the specific activity of the cell concerned.

In my lecture on the sense of hearing I pointed out in detail the great anatomical difficulties attending the theory in question. I endeavoured to show the physical defect of a theory which does not suppose that our sensations of harmony and discord must immediately depend upon the numerical ratios of nerve vibrations transmitted from the ear to the central organ, and I offered a new theory of hearing based upon the analogy of the telephone. According to that theory, there is probably no analysis of sound in the ear; the hair-cells at the peripheral ends of the auditory nerve are probably affected by every audible sound of whatever pitch. When stimulated by sound they probably produce nerve vibrations, simple or compound, whose frequency, amplitude, and wave-form correspond to those of the sound received. The nerve vibrations arriving in the cells of the auditory centre probably induce simple sensations of tones of different pitch, or compound sensations of harmonies or discords strictly dependent on the relative frequencies of the nerve vibrations coming in through the nerve.

I cannot now recapitulate the evidence derived from anatomical, experimental, and pathological observations that give support to my theory of hearing, but I may briefly say that it is opposed to the theory of specific activities, in so far as it has been applied to explain the different qualities of sound sensation. It is, however, in strict accord with the fundamental proposition stated by Fechner [1] in his great work on psychophysics in these words: 'The first, the fundamental hypothesis is, that the activities in our nervous system on which the sensations of light and sound functionally depend are, not less than the light and sound themselves, to be regarded as dependent on vibratory movements.' It is evident that, if we could only comprehend the nature of the molecular movement in the nerve that links the vibration of the physical agent to that in the sensory cell, we could advance towards a true theory of the physiological basis of different qualities of sensation in the different sense-organs. As yet no definite answer can be given to the question, what sort of molecular movement constitutes a nerve impulse, but in recent years our knowledge of the subject has been extended in a direction that opens up a new vista of possibilities.

A nerve impulse travels at a rate not much more than 100 feet per second—an extremely slow speed compared with that of electricity in a wire. It has been thought to be of the nature of a chemical change sweeping along the nerve, but that hypothesis is opposed by the fact that the most delicate thermo-pile shows no production of heat, even when an impulse is caused to sweep repeatedly along the same nerve. Again, it is far easier to fatigue a muscle than a nerve. A living frog's nerve removed from the animal, and therefore deprived of all nutrition, can retain its excitability for nearly an hour, although subjected all the while to thirty or forty stimulations per second. An excised muscle, when similarly stimulated, is exhausted far sooner, because the mechanical energy entirely springs from chemical change in the muscular substance, and therefore the muscle is more easily fatigued than the nerve. The molecular commotion in the excited nerve produces a momentary electrical current; but that result is not peculiar to nerve. The same occurs in muscle when stimulated. Possibly the molecular movement is of the nature of a mechanical vibration; at all events, we now know that a nerve can transmit hundreds, even thousands, of impulses, or let us simply say vibrations, per second. That fact is so important and significant in relation to the physiology

[1] *Elemente der Psychophysik*, 1860. 2nd edition, 1889, part ii. p. 282.

of the sense organs that I show you an experiment to render it more intelligible. A frog's muscle has been hooked to a light lever to record its movement on a smoked cylinder. The nerve of the muscle has been laid on two electrodes connected with the secondary coil of an induction machine. In the primary circuit a vibrating reed has been introduced to serve as a key for making and breaking the circuit, and so stimulating the nerve with periodic induction shocks. If we make the reed long enough to vibrate ten times per second, ten impulses are sent through the nerve to the muscle and ten distinct contractions produced, as shown by the wavy line upon the cylinder. If we shorten the reed so that it will vibrate, say, fifty times per second, the muscle is thrown into a continuous contraction and traces a smooth line on the cylinder; but if we listen to the muscle we can hear a tone having a pitch of fifty vibrations per second, from which we know that fifty nerve impulses are entering the muscle and inducing fifty shocks of chemical discharge in the muscular substance. If we take a reed that vibrates, say, 500 times per second, we hear, on listening to the muscle, a tone having the pitch of 500 vibrations. Observe that we are not dealing with the transmission of electrical shocks along the nerve, but with the transmission of nerve impulses. By stimulating the nerve with wires of a telephone it has been shown by D'Arsonval that a nerve can transmit upwards of 5,000 vibrations per second, and that the wave-forms may be so perfect that the complex electrical waves produced in the telephone by the vowel sounds can be reproduced in the sound of a muscle after having been translated into nerve vibrations and transmitted along a nerve. Such experiments go far in helping us towards a comprehension of the capabilities of nerves in transmitting nerve vibrations of great frequency and complicated wave form; but although they enable us reasonably to suppose that all the fibres of the auditory nerve can transmit nerve vibrations, simple or complex, and with a frequency similar to that of all audible tones, we encounter superlative difficulty in applying such a theory to the sense of sight. In objective sound we have to deal with a comparatively simple wave motion, whose frequency of vibration is not difficult to grasp even at the highest limit of audible sound—about 40,000 vibrations per second. But in objective light the frequency of vibration is so enormous—amounting to hundreds of billions per second—that everyone feels the difficulty of forming any conception of the manner in which different frequencies of ether waves induce differences in colour sensation.

But before passing to colour sense I wish to allude for a moment to the sense of smell. The terminals of the olfactory nerve in the nose are epithelial cells. It has been recently shown by Von Brunn[1] that in man and other mammals the cells have at their free ends very delicate short hairs, resembling those long known in lower vertebrates. These hairs must be the terminal structures affected by substances that induce smell, and are therefore analogous to the hairs on the terminal cells in our organ of hearing. No one ever suggested that the hairs of the auditory cells can analyse sounds by responding to particular vibrations, and I think it quite as improbable that the hairs on any particular olfactory cell respond to the molecular vibrations of any particular substance. If we follow those who have had recourse to the doctrine of specific activities to explain the production of different smells, we must suppose that at least one special epithelial cell and nerve fibre are affected by each different smelling substance. Considering how great is the variety of smells, and that their number increases with the production of new substances, it would be a somewhat serious stretch of imagination to suppose that for each new smell of a substance yet to emerge from the retort of the chemist there is in waiting a special nerve terminal in the nose. It seems to me far simpler to suppose that all the hairs of the olfactory cells are affected by every smelling substance, and that the different qualities of smell result from differences in the frequency and form of the vibrations initiated by the action of the chemical molecules on the olfactory cells and transmitted to the brain. That hypothesis was, I believe, first suggested by Professor Ramsay,[2] of Bristol, in 1882, and it

[1] Von Brunn, *Archiv für mikroskopische Anatomie*, 1892, Band 39, p. 633.
[2] Ramsay, *Nature*, vol. xxvi. 1882, p. 189.

seems to me the only intelligible theory of smell yet offered. But it must be admitted that a theory of smell such as that advanced by Ramsay involves a more subtle conception of the molecular vibrations in nerve fibrils than is required in the case of hearing. It involves the conception that musk, camphor, and similar substances produce their characteristic qualities of smell by setting up nerve vibrations probably of different frequencies and different complexities. We shall see what bearing this may have on the theory of colour sense, to which I now pass.

No impressions derived from external Nature yield so much joy to the mind as our sensations of colour. Pure tones and perfect harmonies produce delightful sensations, but they are outrivalled by the colour effects of a glorious sunset. Without our sense of colour all Nature would appear dressed in bold black and white, or indifferent grey. We would recognise, as now, the beauty of shapely forms, but they would be as the cold engraving contrasted with the brilliant canvas of Titian. The beautiful tints we so readily associate with natural objects are all of them sensations produced in our brain. Paradox though it appear, all Nature is really in darkness. The radiant energy that streams from a sun is but a subtle wave-motion, which produces the common effects of heat on all bodies, dead or living. It does not dispel the darkness of Nature until it falls on a living eye, and produces the sense of light. Objective light is only a wave motion in an etherial medium; subjective light is a sensation produced by molecular vibration in our nerve apparatus.

The sensory mechanism concerned in sight consists of the retina, the optic nerve, and the centre for visual sensation in the occipital lobe of the brain. In the vertebrate eye the fibres of the optic nerve spread out in the inner part of the retina, and are connected with several layers of ganglionic cells placed external to them. The light has to stream through the fibres and ganglionic layers to reach the visual cells—that is, the nerve terminals placed in the outer part of the retina. They may be regarded as epithelial cells, whose peripheral ends are developed into peculiar rod and cone-shaped bodies, while their central ends are in physiological continuity with nerve fibrils. Each rod and cone consists of an inner and an outer segment. The outer segment is a pile of exceedingly thin, transparent, doubly refractive discs, colourless in the cone, but coloured pink or purple in the rod. In man, the inner segment of both rod and cone is colourless and transparent. Its outer part appears to be a compact mass of fine fibrils that pass imperceptibly into the homogeneous-looking protoplasm in the shaft of the cell. Owing to the position of the rods and cones, the light first traverses their inner, then their outer segments, and its unabsorbed portion passes on to the adjacent layer of dark-brown pigment cells by which it is absorbed. It is not necessary for me to discuss the possible difference of function between the rods and cones. I may simply say that in the central part of the yellow spot of the retina, where vision is most acute, and from which we derive most of our impressions of form and colour, the only sensory terminals are the cones. A single cone can enable us to obtain a distinct visual impression. If two small pencils of light fall on the same cone the resulting sensory impression is single. To produce a double impression the luminous pencils must fall on at least two cones. That shows how distinct must be the path pursued by the nerve impulse from a visual cell in the yellow spot to a sensory cell in the brain. The impulses must pursue discrete paths through the apparent labyrinth of nerve fibrils and ganglion cells in the retina to the fibres of the optic nerve. I now pass to the physical agent that stimulates the retina.

When a beam of white light is dispersed by a prism or diffraction grating, the ether-waves are spread out in the order of their frequency of undulation. The undulations of radiant energy extend through a range of many octaves, as Hertz has recently shown, but those able to stimulate the retina are comprised within a range of rather less than one octave, extending from a frequency of about 395 billions per second at the extreme red to about 757 billions at the extreme violet end of the visible spectrum. The ultra-violet waves in the spectrum of sunlight extend through rather more than half an octave. Although mainly revealed by their chemical effects, they are not altogether invisible: their colour is bluish-grey. The only *optical*—that is, strictly *physical*—difference between the several ether-

waves in the visible and invisible spectrum is frequency of undulation, or, otherwise expressed, a difference in wave-length. The *chromatic*—that is, the colour-producing—effects of the ether-waves depend on their power of exciting sensations of colour, which vary with their frequency of undulation.

Although the retina is extremely sensitive to differences in the frequency of ether-waves, it is not equally so for all parts of the spectrum. In the red and blue portions, the frequency varies considerably without producing marked difference of colour effect, but in the region of yellow and green, comparatively slight variations in frequency produce appreciable differences of colour sensation. One striking difference between the effect of ether-waves on the eye and sound-waves on the ear is the absence of anything corresponding to the octave of tone sensation. The ether-waves in the ultra-violet, which have twice the frequency of those of the red end of the spectrum, give rise to no sense of redness, but merely that of a bluish-grey. Even within the octave there are no harmonies or discords of colour sense corresponding to those of tone sensation.

Colours are commonly defined by three qualities or constants—hue, purity, and brightness. Their hue depends upon the chromatic effect of frequency of undulation or wave length. Their purity or saturation depends on freedom from admixture with sensations produced by other colours or by white light. Their brightness or luminosity depends on the degree to which the sensory mechanism is stimulated. The loudness of sound depends on the amount of excitement produced in the auditory mechanism by the amplitude of sound waves; but a sound with small amplitude of undulation may seem loud when the nerve apparatus is unduly sensitive. The brightest colour of the spectrum is orange-yellow, but it does not follow that the amplitude or energy of the ether-waves is greater than in the region of dull red. There is no physical evidence of greater amplitude in the orange-yellow, and its greater luminosity is no doubt purely subjective, and arises from the greater commotion induced in the sensory mechanism.

The theory of colour sense long ago proposed by Sir Isaac Newton [1] is now commonly treated with what seems to me very undeserved neglect. Newton supposed that the rays of light induce vibrations in the retina which are transmitted by its nerve to the sensorium, and there induce different colour sensations according to the length of the incoming vibrations—the longest producing sensations of red and yellow, the shortest blue and violet, those of medium length a sense of green, and a mixture of them all giving a sense of whiteness. At the beginning of this century Thomas Young proposed a theory which seems to have been intended as a modification of that suggested by Newton rather than as a substitute for it. Young supposed that the ether-waves induce vibrations in the retina 'whose frequency must depend on the constitution of its substance; but as it is almost impossible to conceive that each sensitive point of the retina contains an infinite number of particles, each capable of vibrating in unison with every possible undulation, it becomes necessary to suppose the number limited to three primary colours, red, yellow, and blue, and that each sensitive filament of the nerve may consist of three portions, one for each principal colour.' [2] Soon afterwards he substituted green for yellow, and violet for blue, so that he came to regard red, green, and violet as the three fundamental colour sensations, by mixture of which in varying proportions all other colours, including white, are produced. Young believed that his suggestion 'simplified the theory of colours, and might therefore be adopted with advantage until found inconsistent with any of the phenomena.'

Young's trichromic theory of colour sense was adopted by Clerk-Maxwell, and Von Helmholtz amplified the 'three portions' supposed by Young to exist in 'each sensitive filament of the nerve' into three distinct terminals, each having its own nerve fibre. He supposed that each terminal contains a different visual substance capable of being decomposed by light; that when the substance in the red nerve terminal undergoes chemical change its nerve fibre is stimulated,

[1] See quotations from Newton by Thomas Young, 'On the Theory of Light and Colours,' *Phil. Trans. Lond.*, 1802.

[2] *Ibid.*, p. 12.

and the excitement travels to a cell in the brain by whose specific activity the sensation of red arises. In like manner, when the visual substances in the green and violet terminals are decomposed, nerve impulses travel through different fibres to different cells in the vision centre, by whose specific activities the sensations of green and violet arise. With Helmholtz there was no question as to difference in quality of sensation depending on difference in frequency of nerve vibration arriving in the sensorium; no such hypothesis was entertained by him either for tone or for colour sensation. With sight, as with hearing, he supposed that the function of frequency of undulation virtually stops at the nerve terminals in the eye and ear, and that the frequency of undulation of the physical agent has no correlative in the quality of motion passing from the receiving terminal to the sensory cell. He believes that the different frequencies of ether-waves simply excite chemical changes in different nerve terminals. He expressly states [1] that the molecular commotion in the nerve fibres for red, green, and violet is identical in kind, and that its different effects depend on the specific activities of the different cells to which it passes in the sensorium. It is evident that Helmholtz entirely dismissed the Newtonian theory of the production of different qualities of colour sense, and substituted for it the doctrine of his own great teacher, Johannes Müller.

The theory of Young and Helmholtz offers an explanation of so many facts, and has at the same time provoked so much criticism, that I must enter more fully into some of its details. On this theory, the sense of white or grey is supposed to result from a simultaneous and duly balanced stimulation of the red, green, and violet terminals. The red terminals are supposed to be excited chiefly by the longer waves in the region of the red, orange, and yellow, but also by the shorter undulations extending as far as Fraunhofer's line F at the beginning of the blue. In like manner, the green terminals are excited chiefly by the waves of medium length, and to a less extent by the waves extending to about C in the red, and by the shorter waves extending to G in the violet. The violet terminals are stimulated most powerfully by the shorter undulations between F and G, but also by the longer ones reaching as far as D in the yellow; therefore, optically homogeneous light from any part of the spectrum, except its extreme ends, does not usually give rise to a pure colour sensation; all three primary sensations are present, and consequently the colour inclines towards white—the more, the stronger the light.

The experimental facts in support of Young's theory are familiar to all who have studied physics. Compound colour sensations may be produced by causing light of different wave lengths to fall simultaneously or in rapid succession on the same part of the retina. The commonest experimental device is to rapidly whirl discs with sectors of different colours, and observe the results of the mixed sensations; or to cause the images of coloured wafers or papers to fall simultaneously on the retina by Lambert's method; or to transmit light through glass of different colours, and cause the different rays to fall on the same surface; or to mix pure homogeneous light from different parts of the spectrum. For obvious reasons, the last method yields the most trustworthy results. We cannot, by any mixture of homogeneous light from different parts of the spectrum, obtain a pure red or green sensation, and, according to Helmholtz, the same holds true of violet. On the other hand, a mixture of homogeneous rays from the red and green parts produces orange or yellow, according to the proportions employed. A mixture of rays from the green and violet gives rise to intermediate tints of blue, and a mixture of red and violet light produces purple. Therefore, Young regarded red, green, and violet as primary sensations, and orange, yellow, and blue—just as much as purple—he regarded as secondary or compound sensations. Grassmann discovered that to obtain a sense of white or grey it is not necessary to mingle rays from the red, green, and violet portions of the spectrum. He found that he could obtain a white sensation by mixing only *two* optically homogeneous rays from several parts of the right and left sides of the spectrum. The pairs of spectral colours which he found complementary to each other are red and greenish-blue, orange and

[1] Von Helmholtz, *Handbuch der physiologischen Optik*, 2nd edition, 1892, p. 350.

cyan-blue, yellow and ultramarine-blue, greenish-yellow and violet, the complement for pure green being found not in any homogeneous light, but in purple—a mixture of red and violet. The complementary colours may be arranged in a circle, with the complementaries in each pair placed opposite one another. Of course, the circle cannot be completed by the colours of the spectrum; purple must be added to fill in the gap between the red and violet. Helmholtz found no constant ratios between the wave lengths of homogeneous complementaries; and it is a striking fact that, while a mixture of the green and red, or of the green and violet, undulations gives rise to a sensation such as could be produced by rays of intermediate wave length, no such effect follows the mingling of rays from opposite sides of the spectrum. Pure green, with a wave length of 527 millionths of a millimetre, marks the division between the right and left sides. The mixture of blue from the one and yellow from the other side does not produce the intermediate green, but a sensation of white. A mixture of blue or violet and red produces not green, but its complementary—purple. On the trichromic theory, the sense of white produced by the mingling of any of these two colours is simply regarded as the result of a balanced stimulation of the red, green, and violet terminals.

But the anatomical form given by Helmholtz to Young's theory of primary colour sensations is beset with serious difficulties. It implies the existence of three sets of terminals in the retina, and these must all be found in the central part of the yellow spot where cones alone are present. Three sets of cones there would be necessary to respond to the red, green, and violet light, and a colourless pencil of light could not be seen uncoloured, unless it fall on three cones, which we know is not the case. Therefore, if there are three different terminals, they must, in the human retina at all events, be found in every single cone in the yellow spot. In a single cone there might be three sets of fibrils capable of simultaneous stimulation in different degrees, but it seems impossible to suppose that the different vibrations started in the same terminal could be kept discrete, and be transmitted to the brain through three different fibres in the optic nerve, even if the nerve contained a sufficient number of fibres for the purpose, which we know is not the case.

The phenomena of colour-blindness also offer great difficulty. In several cases of apoplectic seizure it has happened that the centre for vision on both sides of the brain has been completely or partially paralysed by the extravasated blood. In such cases the sense of colour may be entirely lost either for a time or permanently, while the sense of light and form remain, although impaired. The loss of colour sense in some cases has been found complete in both eyes; in most of the recorded cases the loss of colour sense was limited to the right or left halves of both eyes; that is, if the lesion affected the vision centre on the right side of the brain, the right halves of both eyes were blind to all colours. That illustrates the well-known fact that a sense of light does not necessarily imply a sense of colour. The colour sense probably involves a more highly refined action of the sensory cell than the mere sense of light and form, and is on that account more liable to be lost when the nutrition of the sensory cell is interfered with. In the normal eye the peripheral zone of the retina is totally blind to colour. If you turn the right eye outwards, close the left, and then move a strip of coloured paper from the left to the right in front of the nose, the image of the paper will first fall on the peripheral zone of the retina, and its form will be seen, though indistinctly, but not its colour. It is difficult to say in that case whether the colour-blindness is due to the state of the retina or to that portion of the vision centre in the brain associated with it. The absence of cones from the peripheral part of the retina has been assigned as the cause, but it is much more probable that the portion of the vision centre associated with the periphery of the retina, being comparatively little used, is less highly developed for form sensation, and not at all for colour sense. It is evident that the production of a sense of white or grey in the absence of all colour sense is not to be explained on the theory that it results from a balanced stimulation of red, green, and violet nerve terminals.

I need scarcely say that colour-blindness has attracted a large share of attention, not only because of its scientific interest, but still more on account of its

practical importance in relation to the correct observation of coloured signals. In 1855 the late Professor George Wilson,[1] of this city, called attention to the growing importance of the subject. Some years ago Professor Holmgren made an elaborate statistical inquiry regarding it at the instance of the Swedish Government, and lately it has been investigated by a committee of the Royal Society of London, who have quite recently published their report.[2]

Although colour-blindness occasionally results from disease of the brain, retina, or optic nerve, it is usually congenital. Total colour-blindness is extremely rare, but partial colour-blindness is not uncommon. It occurs in about 4 per cent. of males, but in less than 1 per 1,000 of females. Its most common form is termed red-green blindness, in which red and green sensations appear to be absent. So far as I can find, the first full and reliable account of the state of vision in red-green blindness is that given in 1859 by Mr. Pole,[3] of London, from an examination of his own case, which appears to be a typical one. The state of his vision is dichromic; his two-colour sensations are yellow and blue. The red, orange, and yellowish-green parts of the spectrum appear to him yellow of different shades. Greenish-blue and violet appear blue, and between the yellow and blue portions of the spectrum, as it appears to him, there is a colourless grey band in the position of the full green of the ordinary spectrum. This neutral band is seen in the spectrum in all cases of dichromic vision. It may appear white or grey according to the intensity of the light, and it apparently results from an equilibrium of the two sensations: no such band is seen in the spectrum by a normal eye. Mr. Pole, in the account of his case given now three and thirty years ago, considered it impossible to explain his dichromic vision on the commonly received theory that his sense of red is alone defective, and that his sense of yellow is a compound of blue and green. He believed his green quite as defective as his red sensation, and that yellow and blue are quite as much entitled to be considered fundamental sensations as red and green. He suggested that in normal colour vision there are at least four primary sensations—red and green, yellow and blue. Professor Hering is commonly accredited with the four-colour theory, but it was previously suggested by Pole.[4]

A year after Pole's paper appeared, Clerk-Maxwell[5] published his celebrated paper on the theory of compound colours, to which he appended an account of his observations on a case of what he believed to be red-blindness, but which we now know must have been red-green blindness. The spectrum appeared dichromic, its only colours being yellow and blue. His description of the case does not materially differ from that given by Pole; but Clerk-Maxwell believed in the trichromic theory of normal vision, and that red-green and blue are the three primary sensations; consequently he supposed that the yellow sensation of a red blind person is not yellow, but green.

It is evident that much depends on the question, Is the yellow sensation of a red-green blind person the same as that of normal vision? For many years it was impossible to give a definite answer to that question, but the answer can now be given, as we shall immediately see. Colour-blindness is frequently hereditary, and two or three cases are known in which the defective colour sense was limited to one eye, while in the other eye colour vision was normal. In such a case observed by Professor Hippel, of Giessen, there was red-green blindness in one eye. Holmgren, who examined Hippel's case, has published an account of it.[6] With one eye all the colours of the spectrum were seen, but to the other eye the spectrum had only two colours with a narrow grey band between them at the junction of the blue and yellow. The yellow seen by the eye with the red-green defect had a

[1] Wilson, *Researches on Colour-blindness*, Edinburgh, 1855.

[2] 'Report of the Committee on Colour Vision,' *Proc. Roy. Soc. Lond.*, July 1892.

[3] W. Pole, 'On Colour-blindness,' *Phil. Trans.*, 1859, vol. cxlix. p. 323.

[4] *Ibid.*, p. 331.

[5] Clerk-Maxwell, 'On the Theory of Compound Colours,' &c., *Phil. Trans.*, 1860, vol. cl. p. 57.

[6] F. Holmgren, 'How do the Colour-blind See the different Colours?' *Proc. Roy. Soc. Lond.*, 1881, vol. xxxi. p. 302.

greenish tinge like that of a lemon, but in other respects the observations confirmed Pole's account of his own case.

Hippel's case seems to me important for another reason. By some it is believed that congenital colour defect is due to the brain. If there had been defective colour sense on one side of the brain, it would not have implicated the whole of one eye, but the half of each eye. Its limitation to one eye, therefore, seems to me to suggest that the fault was in the eye rather than in the brain.

Another interesting fact in this relation is that in every normal eye, just behind the peripheral zone of total colour-blindness, to which I have already referred, there is a narrow zone in which red and green sensations are entirely wanting, while blue and yellow sensations are normal. Possibly the red-green defect is due to an imperfectly developed colour sense in the portion of the vision centre connected with that zone of the retina, but Hippel's case seems to me to show that such defect might be in the retina.

It has probably already struck you that red-green blindness is really blindness to red, green, and violet, that Young's three primary sensations appear to be absent, and the two remaining colours are those which he regarded as secondary compounds of his primaries.

That, however, is not all that is revealed by colour-blindness. There is at least another well-known though rare form in which a sense of yellow, blue, and violet is absent, and the only colour sensations present are red and green. The defect is sometimes termed violet blindness, but the term is somewhat misleading. It is much more in accordance with the fact to term it yellow-blue blindness; indeed, we would define it precisely by terming it yellow-blue-violet blindness. Holmgren[1] has recorded a unilateral case of that defect analogous to Hippel's case of unilateral red-green defect; we therefore know definitely how the spectrum appears to such a person. In the case referred to all the colours of the spectrum were seen with the normal eye, but to the other eye the spectrum had only two colours, red and green. The red colour extended over the whole left side of the spectrum to a neutral band in the yellow-green, a little to the right of Fraunhofer's line D. All the right side of the spectrum was green as far as the beginning of the violet, where it 'ended with a sharp limit (about the line G).'

If you turn to the Report of the Royal Society's Committee[2] on colour vision, you will find the spectrum as it appears to yellow-blue-violet blind persons. The plate agrees with the description of Holmgren's case already given; but you will not find a representation of the spectrum as it appears to those who are red-green blind, and as described by Pole and others. In place of it you will find two dichromic spectra, one with a red and blue half, said to be seen by a green blind, the other with a green and a blue half, said to be seen by a red blind person. We have copied the spectra for your inspection, and you will observe that yellow does not appear in either of them. I do not for a moment pretend to criticise these spectra from any observations of my own; I am aware Holmgren maintains that red-and-green blindness may occur separately; but, on the other hand, Hering and Stilling have maintained that they are always associated, and Dr. George Berry, an eminent ophthalmologist, has assured me, from his own observations, that such is the case.

Of the various methods of testing colour vision, that suggested by Seebeck is most commonly employed. The individual is mainly tested with regard to his sense of green and red. He is shown skeins of wool, one pale green, another pink or purple, and a third bright red, and he is asked to select from a heap of coloured wools, laid on a white cloth, the colours that appear to him to match those of the several tests. We have arranged such test skeins for your inspection, and have placed beneath each of them the colours which a red-green blind person usually selects as having hues similar to those of the test. It is startling enough to find brown, orange, green, and grey confused with bright red; pale red, orange, yellow, and grey confused with green; blue, violet, and green confused with pink; but

[1] 'How do the Colour-blind See the different Colours?' *Proc. Roy. Soc. Lond.*, 1881, vol. xxxi. p. 306.

[2] Report on Colour Vision, *lib. cit.*, plate i. No. 4.

these confusions have all their explanation in the fact that the red-green blind have only two colour sensations—yellow and blue—with a grey band in what should have been the green part of his spectrum.

We have now to show you another and far more beautiful method of ascertaining what fundamental colour sensations are absent in the colour-blind. It is the method of testing them by what Chevreul long ago termed *simultaneous contrast*. If in a semi-darkened room we throw a beam of coloured light on a white screen and interpose an opaque object in its path, the shadow shows the complementary colour. If the light be red, the shadow appears green-blue; if it be green, the shadow appears purple or red according to the nature of the green light employed. If the light is yellow, the shadow is blue; if it is blue, the shadow is yellow. We must remember that the part of the screen on which the shadow falls is not entirely dark; a little diffuse light falls on the retina from the shadowed part, so that the retina and vision centre are slightly stimulated, where the image of the shadow falls. We use an oxyhydrogen lantern and transmit the light through plates of coloured glass carefully selected.

The experiment is rendered still more striking, though at the same time a little more complicated, by using two oxyhydrogen lamps and throwing their light on the same portion of the screen. If a plate of coloured—say ruby—glass is held before one of the lamps, and an opaque object such as the head of a T-square is placed in the path of both lights, the shadow cast by the white light falls on a surface illuminated by a red light, and shows a deep red far more saturated than the surrounding surface of the screen where the red and white lights fall. The shadow cast by the red light shows the complementary bluish green; and the contrast of the two is exceedingly striking. When we use a plate of pure green glass, the shadow showing the inducing colour is a saturated green, the other shows the complementary purple. With yellow glass one shadow is deep yellow, the other pale blue. With blue glass one shadow is saturated blue, the other pale yellow. With pink glass the *complementary green is deeper* than the shadow showing the inducing pink, and is on that account very striking.

These experiments which we have shown you point to some subtle physiological relations between complementary colours. A colour sensation produced in one part of the vision apparatus forces, so to speak, the neighbouring part, which is relatively quiescent, to produce the complementary colour subjectively. I say *vision-centre* rather than *retina*, because, if one eye is illuminated with coloured light while the other eye is feebly illuminated with white light, the complementary colour appears in the centre belonging to that eye. The sense of white appears to be a mysterious unity; if you *objectively* call up one part of the sensation, you call up its counterpart *subjectively*. If a colour and its complementary counterpart be both displayed objectively at the same time, the action and reaction of effect afford a sensation far more agreeable than is producible by the objective display of only one of them. The agreeableness of the contrast of complementary colours, no doubt, springs from the harmony of effect. There is no harmony of colour effect analogous to that of music, but there is harmony of a different kind, and that harmony is formed by the contrast of complementary colours.

Now I imagine many of you have already anticipated the question, What information can simultaneous contrast give regarding the fundamental sensations of the colour-blind? From an extended series of observations Dr. Stilling,[1] of Cassel, has ascertained that if a person cannot distinguish between red and green, no complementary colour appears in the shadow when the inducing light is red or green, but if the inducing light is yellow or blue the proper complementary appears in the shadow. If a person was blind to red, he never found the complementary green appear; if he was blind to green, he never found the complementary red appear. When the inducing light appeared colourless, the shadow was also colourless. Stilling therefore concluded that either the sensations of red and green or of blue and yellow were wanting at the same time or all colour sense was absent.

[1] J. Stilling, 'The Present Aspect of the Colour Question,' *Archives of Ophthalmology*, 1879, viii. p. 164.

It is difficult to see how these results are to be harmonised with the conclusions arrived at by the Committee of the Royal Society.

Facts such as these are regarded by some as lending support to the theory of colour sense proposed by Professor Hering, of Prague.[1] He supposes that the diversity of our visual perceptions arises from six fundamental sensations constituting three pairs—white and black, red and green, yellow and blue. The three pairs of sensations are supposed to arise from chemical changes in three visual substances not confined to the retina, but contained also in the optic nerve and in the vision centre.[2] He imagines that a sense of white results from *decomposition* induced in a special visual substance by all visible rays, and that the *restitution* of the same substance produces a sense of black. The sensations of the red and green pair are supposed to arise, the one from decomposition, the other from restitution of a second substance; while yellow and blue are supposed to result from decomposition and restitution of a third substance. From our knowledge of photo-chemical processes we can readily suppose that light induces chemical change in the visual apparatus; but that the wave-lengths in the red and yellow parts of the spectrum induce *decomposition*, while the wave-lengths in the green and blue induce *restitution* of substances, it is difficult to believe. How such a visual mechanism could work it would be difficult to comprehend; for example, if we look at a bright red light for a few moments and then close our eyes, the sensation remains for a time, but changes from red to green and then slowly fades away. According to Hering's theory, the green after-sensation results from the restitution of a substance decomposed by the red light. But if we reverse the experiment by looking at a bright *green* light and then closing our eyes, the after-sensation changes to *red*. The theory in question would require us to suppose that the green light builds up a visual substance which spontaneously decomposes when the eyes are closed, and so produces the red after-image. I confess that such an hypothesis seems to me incredible. Another remarkable feature of Hering's theory is that colours termed *complementary* ought to be termed *antagonistic*,[3] because they are capable of producing a colourless sensation when mingled in due proportions. If the complementary colours yellow and blue could, when mixed, produce black, they might well be named 'antagonistic'; but since their combined effect is a sense of whiteness, and since the addition of them to white light increases its luminosity, it seems very difficult to comprehend on what ground the term *antagonistic* should be substituted for *complementary*. I confess I am quite unable to follow Hering when he supposes that three pairs of mutually antagonistic chemical processes are produced in the retina when white light falls on it, that these processes are all continued on through the optic nerve into the vision centre, and there give rise to our different light and colour sensations.

In 1881 Professor Preyer contributed an important paper on colour sense,[4] in which he supported Young's theory of primary colour sensations, but assuming their number to be four instead of three. Believing with Schultze that the cones are the only terminals in the retina concerned in colour sense, Preyer supposes there are four sets of cones containing different photo-chemical substances which are severally affected by undulations in the red, yellow, green, and blue parts of the spectrum. But since it has been calculated that the cones are thrice as numerous as the fibres of the optic nerve, Preyer has endeavoured to bring the Helmholtz amplification of Young's theory within the range of anatomical possibility by supposing that the four sets of cones are arranged in pairs, each pair being connected with one nerve fibre. This hypothesis, however, could not meet the case, even if cones were the only visual terminals. The rods are far more numerous than the cones; therefore, although it is probable that in the yellow spot each nerve fibre is connected with only one or two cones, elsewhere in the retina

[1] E. Hering, *Zur Lehre vom Lichtsinne*, 2nd ed. Vienna, 1878.
[2] Hering, *ibid.*, p. 75.
[3] Hering, *ibid.*, p. 121.
[4] W. Preyer, 'Über den Farben und Temperatur Sinn, mit besonderer Rücksicht auf Farbenblindheit,' *Archiv für Physiologie*, 1881, vol. xxv. p. 31.

each fibre must be connected with several terminals, the number increasing more and more towards the periphery of the retina, where the power of perceiving a double impression is far less than at the yellow spot. Preyer supposes that the pairs of cones are in two sets mingled together; the pairs of one set being for the reception of red and green stimulation, the other for yellow and blue. The part of Preyer's theory that appears to me attractive is that the photo-chemical changes induced in the several terminals cause vibrations to be transmitted through the nerve whose frequency must be far less than that of the undulations of the ether, and their wave-length consequently far greater, but 'the ratios of the wave-lengths of the ether and nerve vibrations probably remaining almost unchanged.'[1] If Preyer had only gone a step further and supposed that different colour sensations are producible in the same cells by different frequencies of vibrations entering the sensorium through the same nerve fibres, I would gladly have assented to a theory which would have been essentially a return to that of Newton; but my learned friend still strives to account for different colour sensations on the doctrine of specific activities, and to support the idea that different visual substances are located in different optic terminals. He supposes that when the cones of the red-green pair are simultaneously stimulated, vibrations of different frequencies are transmitted to a ganglion cell in the retina, and thence to a fibre of the optic nerve, but *not simultaneously*. He does not entertain the idea that the two sets of vibrations are compounded, and so transmitted by the fibre; on the contrary, he believes that 'one and the same nerve fibre cannot be stimulated in a double manner at the same moment,' and therefore, to explain the transmission of vibrations of two frequencies by the same fibre, he supposes that there must be a rapidly alternating transmission of the two sets of vibrations. I feel unable to assent to that idea, for it appears to me that if an undulatory theory is applicable to nerve action, we must believe that simple pendular vibrations of different frequencies can be compounded. Nor do I feel able to assent to Professor Preyer's theory of the production of two qualities of sensation—say red and green—by vibrations transmitted through the same fibre. Reduced to the simplest expression, his theory is, that the fibre eventually ends in two sensory cells of specifically different activities, one producing a red. the other a green sensation; that these two cells are affected sympathetically by vibrations of different frequencies—the red cell by vibrations of the frequency transmitted from the red cone, the green by those of the frequency transmitted from the green cone. It seems to me far simpler to suppose that the vibrations produced by chemical change in visual substances in the retina may be transmitted either as simple or compound vibrations simultaneously by the same nerve fibres, and produce different sensations in the same cells, according to frequency and complexity of the incoming vibrations.

It seems to me that the difficulty of this question is much increased by attempting to show that different cones are concerned in the reception of different colour impressions. In support of such a view, the fact is adduced that, in birds and some reptiles, each cone contains an oil globule of a red or orange colour in some cones, and of a yellow or greenish-yellow in others. The coloured spheroid is placed in the outer part of the inner segment immediately internal to the outer segment, and must exercise a selective absorption on the light passing to the outer segment. The presence of these coloured spheroids is remarkable, but we know as little regarding their physiological significance as we do regarding that of the yellow pigment in the internal layers of the retina at the yellow spot in our own eyes, through which all the light must pass ere it can reach the inner segments of the cones in that portion of the retina. All the cones in the human eye, as in that of all mammals, are colourless, and it involves serious difficulty if we suppose that different cones are affected by red, green, yellow, and blue light. The image of a coloured star, small enough to fall on only one cone, can be seen of a fixed and definite colour, that does not alter when the position of the eye is changed, and the image shifted from one cone to another in the yellow spot. That fact alone seems to me sufficient to show the necessity for supposing that each cone is capable of stimulation by all visible undulations of light, and of

[1] Preyer, *ibid.*, p. 98.

transmitting such nerve vibrations as are capable of inducing all the colour sensations.

It further appears to me that the difficulty of the case is increased by attempting to show that cones are the only optic terminals concerned in colour impressions, while the rods minister only to a sense of light. It is true that cones are relatively few in number, or may indeed be absent from the retina of nocturnal animals, such as night-flying owls and bats, but that cannot be regarded as proof that the rods are not concerned in colour sense. Rods are much more numerous than cones everywhere in the human retina, save at the yellow spot. Throughout the greater part of the retina the cones occur singly, surrounded by numerous rods. Yet when the image of a coloured star, small enough for the area of a single cone, is made to fall on parts of the retina peripheral to the yellow spot, its colour does not disappear, and reappear when the eye is moved, as would inevitably happen if the rods were not terminals concerned, as well as the cones, in colour sense.

It must be admitted that the production of nerve impulses within the terminals in the retina is almost as obscure as ever. It is still the old question, Does light stimulate the optic terminals by inducing vibration, or by setting up chemical change? Whichever view we adopt, it seems to me necessary to suppose that all the processes for the production of nerve impulses can take place in one and the same visual cell, and are transmitted to the brain through the same nerve fibre.

I referred to the sense of smell because it seems to me that we cannot in that case escape from the conclusion that the different sensations arise from different molecular stimulations of the same olfactory terminals.

From Lippmann's recent researches on the photography of colour[1] it appears that all parts of the spectrum can now be photographed on films of albumino-bromide of silver to which two aniline substances, azaline and cyanine, have been added. It seems, therefore, reasonable to suppose that a relatively small number of substances could enable all the rays of the visible spectrum to affect the retina. Helmholtz believes that three visual substances would suffice; but if the primary sensations are to be regarded as four—red, green, yellow, and blue—at least four visual substances appear to be necessary; and I think we must assume that all of them are to be found in the same visual cell in the retina, and that the nerve impulses which their decompositions give rise to are all transmitted through the same optic fibres to the brain cells, there to produce a sense of uncoloured or coloured light. Evidently such an hypothesis is not altogether novel; it is essentially a return to that long ago suggested by Newton. The only difference is that light is supposed to induce photo-chemical changes in the retina, as Von Helmholtz suggested, instead of mere mechanical vibration, as Newton supposed. But if in the sense of smell nerve undulations are induced by mechanical vibrations of molecules acting on delicate hairs at the ends of cells, is it, after all, so very unreasonable to suppose that within each visual cell there may be different kinds of molecules that vibrate in different modes when excited by ether waves? Four or five sets of such molecules in each terminal element in the retina would probably be sufficient to project successively or simultaneously special forms of undulations through the optic nerve, to induce colour sensations differing according to the wave form of the incoming nerve undulation.

The photo-chemical hypothesis has much in its favour. We know how rapidly light can induce chemical change in photographic films, and we know that light induces chemical change in the vision-purple in the outer segments of the rod cells in the retina. The fact that the cones contain no vision-purple is no argument against the theory, for the inner segment of both rod and cone is by many regarded as the true nerve terminal, and there is no vision-purple in either of them. The visual substances in the cones, at all events, are colourless, and the existence of them as substances capable of producing nerve impulses by chemical decomposition is as yet only a speculation awaiting proof. The fatigue of the retina produced by bright light is best explained on a chemical

[1] G. Lippmann, 'On the Photography of Colour,' *Comptes Rendus*, 1892, tome cxiv. p. 961.

theory, but it could also be explained on a mechanical theory, for we must remember that, even if the nerve impulses produced in the visual cells were merely a translation of the energy of light into vibration of nerve molecules, the nerve impulse has to pass through layers of ganglionic cells before reaching the fibres of the optic nerve, and in these cells it probably always induces chemical change. The phenomena of partial colour-blindness could be explained on a photo-chemical theory by supposing that it arises from the absence of the substances required to produce the wave forms necessary for the colour sensation which is defective, but the total colour-blindness at the anterior part of the retina is evidently a difficulty. How could we have a sense of light from that portion of the retina if all the visual substances are absent? That is one of the reasons why Hering supposed that a special visual substance is present everywhere in the retina, which by decomposition gives rise to a sense of light as distinguished from colour. But even on the hypothesis we are pursuing, it is not necessary to suppose that all visual substance is absent, for the colour-blindness in the front of the retina could be explained by supposing that colour perception has not been developed in the corresponding portion of the vision centre, and consequently all nerve impulses coming from that part of the retina produce scarcely anything more than a sense of light.

If the photo-chemical theory is entertained, it seems necessary to suppose that there is some singular relation between the pairs of substances which respectively give rise to red and green, and yellow and blue, seeing that both members of a pair frequently, if not always, fail together.

It seems to me that the great difficulty arises when we consider the puzzling phenomena of contrast. If light of a particular wave length decomposes a special substance, and gives rise to, say, a sense of red, why does the complementary bluish-green sensation appear in the remainder of the vision centre? If the induced colour were a pure green, one might attempt to explain it by supposing that a sympathetic change had been induced in a substance closely related to that suffering decomposition by the objective light, but no such simple explanation is admissible; the complementary contrast of red is not green, but a mixture of green and blue. The inadmissibility of such an explanation becomes still more apparent if we take pure green as the inducing colour—the complementary contrast that appears is purple, which involves a blue or violet, as well as a red sensation. It matters not what inducing colour sensation we employ, the induced contrast is always the complementary required to produce a sense of white. George Wilson[1] long ago suggested that simultaneous contrast probably arises from a 'polar manifestation of force'; indeed, he regarded it as a 'true, though unrecognised, manifestation of polarity.' It is enough to mention that interesting suggestion, but I must not pursue it, for we are dealing with a problem that has as yet baffled the wit of man.

I have placed before you a subject that involves physical and physiological considerations of extreme difficulty. I have endeavoured to show the nature of these difficulties, and although I have not attempted to solve them all, I have at all events sought to show reasons why we should refer our different colour sensations to differences in the nerve vibrations transmitted from the optic terminals rather than to specifically different activities of cells in the vision centre. Although I have no hesitation in adopting a tetrachromic in place of a trichromic theory of normal vision, I am unable to relinquish the essential part of Young's theory—that there is a relatively small number of primary colour sensations. To abandon that idea entirely, as Krenckel and Berry[2] have done, is to return to the Newtonian theory, the difficulties of which none knew better than Thomas Young. I have not found it an agreeable task to point out the shortcomings of some theories advanced by those for whom I have the deepest regard; but in the progress of scientific thought it is especially necessary to keep our minds free from the thraldom of

[1] Wilson, *Researches on Colour-blindness*, Edinburgh, 1855, p. 179.

[2] G. Berry, 'Examination of Cases of Colour-blindness,' *Edin. Med. Jour.*, Oct. 1879, and 'Critical Remarks on the Theories of Fundamental Colour Sensations,' *London Ophthalmic Hospital Reports*, 1890–91.

established theory, for theories are but the leaves of the tree of science; they bud and expand, and in time they fade and fall, but they enable the tree to breathe and live. If this address has been full of speculation, I trust you will allow that the scientific use of the imagination is a necessary stimulus to thought, by which alone we can break a path through the dense thicket of the unknown that surrounds us.

The following Reports and Papers were read:—

1. *Fifth Report of the Committee on the Present State of our Knowledge of the Zoology and Botany of the West India Islands, and on taking steps to investigate ascertained Deficiencies in the Fauna and Flora.*—See Reports, p. 353.

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2. *Report of the Committee for carrying on a definite piece of Work at the Zoological Station at Naples.*—See Reports, p. 344.

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3. *Draft of Report of the Committee on the Present State of our Knowledge of the Zoology of the Sandwich Islands.*—See Reports, p. 355.

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4. *Fifth Report of the Committee appointed for the purpose of taking steps for the establishment of a Botanical Laboratory at Peradeniya, Ceylon.*—See Reports, p. 363.

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5. *Report of a Committee on the Migration of Birds at Lighthouses and Light-vessels.*—See Reports, p. 366.

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6. *Report of the Committee appointed for the purpose of arranging for the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth.*—See Reports, p. 356.

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7. *Report of the Committee for Improving and Experimenting with a Deep-sea Tow-net, for opening and closing under water.*—See Reports, p. 366.

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8. *Report of the Committee appointed to consider proposals for the Legislative Protection of Wild-birds' Eggs.*—See Reports, p. 366.

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9. *On the Physiology of Protoplasm.* *By* Professor W. PREYER.

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10. *On Rabl's Doctrine of the Personality of the Segments of the Nucleus, and Weismann's 'Idant' Theory of Heredity.* *By* Professor MARCUS HARTOG, *D.Sc., M.A.*

The nucleus of a cell about to divide undergoes the following changes:—

The hyaloplasmic structures become ultimately resolved into threads of approximately the same size. The chromatin or nuclein granules become nearly uniform in size, and are grouped in single file along the threads or segments which thus constitute the *nuclear segments* or *chromosomes* of Boveri, the 'idants' of

Weismann. The file of granules next becomes double, probably owing to their bipartition, and the nuclear segments widen out, as a preparation for splitting between the two lines of granules. The nuclear wall now disappears; the nuclear segments become grouped about the centre of the cell, constituting the 'equatorial plate' of Strasburger, the 'monastroid' of Flemming, and the cytoplasm shows a bipolar arrangement. Each segment splits into two secondary segments, one of which goes to either pole of the cell, and the assemblage of these daughter segments receiving a wall constitutes the nucleus of the daughter cell. On their way to the pole the daughter segments are usually Λ-shaped with the apex in front, and they frequently retain this shape for some time in the young nucleus, giving it a polar or monaxial structure. Rabl, who found traces of this arrangement persist in the 'resting nucleus' of the larval salamander, formed the generalisation that *the threads formed in an old nucleus on its preparations for division are the same as those which constituted it on its original formation;* and that *where this arrangement is seemingly lost in the 'resting nucleus' definite paths exist along which the errant granules return to their original stations to re-form* identical *segments.* This we may term Rabl's 'doctrine of the personality of the nuclear segments.' On the assumption of the truth of this doctrine Weismann has based a complex theory of heredity, fully and finally developed in his essay on Amphimixis; but despite its ingenuity it must fall if Rabl's doctrine is not proved. But Rabl's doctrine has never commanded the universal assent of histologists, and the author's researches have yielded additional evidence against it. He adduces the following arguments:—

1. The resting nucleus, in the vast majority of cases, shows no trace of polar structure, but a network of protoplasm which is either impregnated with chromatin, or bears on its threads chromatin granules of irregular size; and this network, granules and all, is probably in constant motion. Such a nucleus, characteristic of tissue cells and most brood-mother cells, such as ovarian ova, &c., is sometimes found even between successive brood divisions. Hence we infer that Rabl's polar type of nucleus is characteristic not of the resting state but of the absence of it, the preparations for a new division supervening before the nucleus has as it were settled down from its constitution.

2. In the pollen mother cells of *Tradescantia* spp., on their first division, the segments undergo changes (now first described by the author) during the reconstitution of the nucleus, which give no support to Rabl's doctrine.

3. In the resting nucleus of the ordinary type there is no indication of a path by which the granules could return to their primitive position.

4. The chromatin granules themselves should have a personality if Rabl's doctrine be correct; but in the ordinary resting nucleus they are subject to increase and decrease of size, probably appearance and disappearance—phenomena which make their personality doubtful.

5. In certain cases of brood-cell formation, *not all* the segments of the equatorial plate are divided between two equivalent daughter nuclei. In *Hemerocallis fulva* some segments pass laterally to form one or more lateral nuclei (Strasburger). In Tradescantia some segments may be retarded, and stay in the cytoplasm (as now shown by the author). On Rabl's doctrine the personality of the pollen grains should be defective, with a corresponding result in the offspring; on Weismann's theory these groups should evince increased variability, but neither anomaly has been observed.

6. The nucleus of the brood-mother cell of most gametes on its first division presents a number of segments which is half of the number that constituted the nucleus on its formation. As the mitosis is often in all other respects normal, this process of 'reduction' is irreconcilable with Rabl's doctrine, and Weismann's explanations based on purely hypothetical differences from ordinary mitosis are inadmissible.

7. In some cases a cell on its mitosis presents a greater number of segments than those which constituted its nucleus on formation. Thus in the embryo-sac of *Lilium* the first mitosis shows twelve nuclear segments; but the second mitosis shows sixteen in the lower cell, while the upper repeats twelve segments. Such

nuclear 'augmentation' is as inexplicable on Rabl's doctrine as the 'reduction' described in (6).

The author concludes that Rabl's doctrine of the personality of the nuclear segments is not itself firmly enough established to serve as the foundation of any wide-reaching theory.

FRIDAY, AUGUST 5.

The following Papers were read:—

DEPARTMENT OF BOTANY.

1. *A Proposed World's Congress of Botanists at Chicago in* 1893. *By* Dr. J. C. ARTHUR.

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2. *Observations on Secondary Tissues in Monocotyledons.* *By* D. H. SCOTT, *M.A., Ph.D., F.L.S., and* GEORGE BREBNER.

1. Origin of secondary tracheides in *Dracæna* and *Yucca*.

Two contradictory views have been held on this question. On the one hand Krabbe, Röseler, and Strasburger maintain that these elements are true tracheides, each arising from the elongation of a single cambial cell. On the other hand Kny, Mdlle. Loven, and Wieler regard them as short vessels arising by the fusion of a series of cambial cells. To this view one of the authors of the paper (Dr. Scott) formerly inclined.

A more complete investigation has, however, shown that the appearances of cell-fusion are illusory, and that each tracheide develops simply by the enormous growth in length of one cell. The nucleus usually remains undivided. The tracheides have been observed, both in sections and in macerated preparations, at all stages of their growth. The definite decision of this point is of interest, as establishing some of the most striking instances of 'sliding growth.' These tracheides often grow to forty times their original length, and that in a region which, as a whole, undergoes no elongation. Thus the whole room required for the growth of these elements has to be provided by mutual displacement of cells.

2. Growth in thickness of the roots of *Dracæna*.

When a cambium arises outside the vascular bundles it is usually formed in the pericycle. In these roots we have a conspicuous exception to the rule, for here it is quite common for the cambium to appear in the cortex, outside the endodermis. In *Dracæna Draco, D. fragrans*, and *D. ensifolia* the authors found that the cambium is often formed in the cortex at once, without any previous pericyclic development. The two modes of growth, however, often occur side by side, or combined in the most irregular manner. Connecting vascular bundles, passing through the endodermis, were often observed.

A new point of importance is that in most cases observed, the secondary growth starts from the insertion of a rootlet, advancing upwards and downwards, as well as peripherally, from this place. At and near the insertion of the rootlet the cambium is always pericyclic; at a distance from it cortical cambium begins to appear, while at a still greater distance the pericyclic cambium disappears, and the formation of secondary tissues is limited to the cortex.

3. Secondary thickening in *Iridaceæ*.

The authors are not aware that any example of this has been described before. Their attention was called by Professor Bower to the occurrence of secondary thickening in *Aristea corymbosa*, Ait., an iridaceous shrub. The process has now been fully investigated, and agrees generally with the *Dracæna* type. The young stem of *Aristea* is flattened in the plane of the distichous and equitant leaves. The primary vascular cylinder is thus narrowly elliptical in transverse section.

The primary development ceases for a considerable time before the cambium appears. The formation of secondary tissue is at first most active at the sides of the cylinder. At its narrow edges the process begins later, and for a long time is less active. Hence the vascular cylinder gradually acquires a circular transverse section. The secondary vascular bundles are concentric; their xylem consists chiefly of long tracheides, which have a tortuous course, and arise, like those of *Dracæna* and *Yucca*, by the elongation of single cells.

Here, as in other Monocotyledons, the cambium does not form a single initial layer of cells, but rather constitutes a secondary meristematic zone in which several layers may successively take up the cambial divisions.

The first-formed periderm is external at the sides, internal at the prominent edges of the flattened stem. This helps to give the older stem a cylindrical form.

At a later stage successive internal periderms arise, and soon the whole of the primary cortex is thrown off. This is meanwhile replaced by the formation of abundant secondary cortex on the outer side of the cambial zone. The outer layers of the secondary cortex also are successively cut off as bark.

It is evident that a process of secondary growth of the same general type has appeared independently in several distinct groups of Monocotyledons.

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3. *On the Simplest Form of Mosses.* *By* Professor Dr. Goebel, *For.F.L.S.*

Since Hofmeister's researches proved that the moss sporogonium is the homologue of the leafy spore-forming fern-plant, and the sexual moss-plant is the homologue of the fern prothallus, it has been the endeavour of many morphologists to discover how the transition from the moss sporogonium to the fern-plant took place. These efforts have, however, led to no result. They started from the assumption that vascular cryptogams sprang from moss-like ancestors. My investigations early led me to regard such a view as erroneous, and to the conclusion that mosses and ferns do not stand in *direct* genetic connection, but have been derived from a common stock. The character of this alga-like ancestor we must seek for in the sexual generation, whilst the asexual generation in the moss series and in the fern series has developed differently.

Now we see the sexual generation of the moss beginning as a simple structure —the protonema—often mistaken for a filamentous alga. A similar structure is found in the prothallus of Hymenophylleæ, and in the beginning of the development in the prothallus of most other ferns. The moss-plants arise out of the protonema as lateral shoots. They were originally only the supports of the sexual organs, for the protection of which envelopes were formed. If, now, the sexual organs were developed, not coincidently with the formation of the moss-stem, but only at a later period, then the envelopes of the sexual organs might serve for assimilation as leaves, and thus might arise the moss-plant as we have it now.

The simplest moss-plant was, then, one in which the sexual organs were seated on the protonema, surrounded by one or several leaf-like envelopes. Such a form has hitherto been hypothetical, but I have had the good fortune to discover its existence in Buxbaumia.

The male plants of this moss are of a wonderfully simple character, and correspond exactly with the hypothetical form just referred to. From primary delicate protonema-threads a thicker branch takes origin, at the end of which is a single antheridium, long-stalked like that of a liverwort, and corresponding otherwise in form with that of liverworts.

Around this antheridium is a curved shell-like envelope, which has no chlorophyll, and differs also from other known moss-leaves in the arrangement of its cells, there being no two-sided apical cell. No stem is formed, the only indication of it being the formation of one or two oblique segment walls in the cell beneath the leaf-insertion.

The female plant is more highly developed, as one would expect from a biological point of view. The formation of the embryo demands a considerable food supply, and therefore a cell mass of some bulk must be developed. A similar arrangement to the one I describe is seen in the filamentous prothalli of the

Hymenophylleæ, in which the antheridia are directly sessile on the filaments, whilst the archegonia stand upon a cushion of cell-tissue, the archegoniophore, produced by the division in a longitudinal direction of a prothallus-filament. This female plant in Buxbaumia is an archegoniophore, with envelopes composed of a number of leaf-like structures without chlorophyll, which correspond with the single envelope leaf of the male plant. Only one archegonium is developed.

The sexual generation of Buxbaumia possesses, then, an extremely simple construction, and in my opinion exhibits the nearest approach known to the ancestral form of the mosses. One might, of course, conjecture that this simplicity of construction is a reduction from a more complex; but against this view may be urged that Buxbaumia possesses characters which separate it from the other mosses, and which remind us of the liverworts, chiefly of a low stage in development. These characters are:—

1. Form of antheridium; which is very different from that of Bryineæ, and corresponds with that of many liverworts.

2. The arrangement of the cells in the leaf.

3. The fact that the marginal cells of the leaf normally grow out into protonema-threads, which shows that the leaves are merely expanded protonemata, an assumption which is supported by other facts.

The author believes, then, that Buxbaumia has preserved in its sexual generation the primitive characters, and is a very old type.

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4. *On the Cause of Physiological Action at a Distance.* *By* Professor L. Errera (*Brussels*).

Most vegetable organs are sensitive to the influences of their environment, and respond to these stimuli, as long as they are capable of growth by bending in a definite direction. In fact, they generally feel asymmetrical distribution of matter or energy around them. Thus the geotropic, heliotropic, hydrotropic, haptotropic curvatures arise which are familiar to vegetable physiologists.

But the very interesting phenomena described two years ago by Elfving did not appear to belong to any of the known categories, and led this distinguished botanist to the assumption of a new force revealing itself by 'physiological action at a distance,' as he terms it.

He found that pieces of iron, and to a less degree of zinc or aluminium, as well as different organic substances—sealing-wax, rosin, roots of living plants—attract the growing, sporangium-bearing filaments of *Phycomyces nitens*, a well-known fungus belonging to the Mucorini. All other metals tried by Elfving were inactive, whereas the filaments of *Phycomyces* itself showed a mutual repulsion.

The latter fact, which I had often observed, I always ascribed to negative hydrotropism. So the question arose whether the attractions discovered by Elfving are not due to a similar cause. For, just as we know that a surface which emits moisture repels the *Phycomyces* filaments, it seemed probable that moisture-absorbing substances should produce the reverse effect and attract them. Now iron certainly absorbs aqueous vapour whilst rusting, and its peculiar action on *Phycomyces* might thus be simply a case of hydrotropism.

I have tested this view by a great number of experiments, and I submit for the inspection of the members of this section photographs showing the behaviour of *Phycomyces* towards different substances. This theory enables one not only to explain the known facts, but it also permits one to predict unknown ones.

It is easy to demonstrate that any modification of iron which lessens its capacity of rusting at the same time diminishes its attraction on *Phycomyces:* polished steel scarcely attracts, and nickelled steel does not do so at all.

China clay, which is very hygroscopic, attracts energetically, but china exhibits no attraction. One of the most striking instances is that of agate and rock-crystal. Although both are essentially formed of silica, the Japanese physicist Ihmori[1] has shown that the former is very hygroscopic, whereas the latter is not so. And, as was to be foreseen, agate strongly attracts the *Phycomyces*, though rock-crystal

[1] *Wiedemann's Annalen*, 1887, xxxi. p. 1006.

is perfectly inactive. I might quote many similar facts, if necessary. Thus, sulphuric acid, sulphate of copper, &c., are strongly attractive. Certain bodies which are only moderately hygroscopic, as white soap, lose or gain moisture according to the degree of dampness of the surrounding atmosphere; and in the first case they repel *Phycomyces*, in the second they attract.

The sensibility of *Phycomyces* is, in fact, so great that it may actually be used as a reagent to test the existence of hygroscopic power. Having noticed that camphor very distinctly attracts the filaments, and thymol does not (although both of these substances have a deleterious action on them), I could anticipate that camphor is hygroscopic—a fact which, though unknown to chemists, was confirmed by careful weighing.

Lastly, the theory may be tested in another way. Differing from filaments of *Phycomyces*, roots of higher plants are positively hygroscopic. Then, as might be expected, they bend away from iron instead of being attracted by it.

All these experiments succeed also in a saturated atmosphere, which shows that hydrotropism is not due, as generally admitted, to differences in the hygrometric state of the air. But the discussion of this point, as well as certain deductions relative to the physical phenomenon of hygroscopicity, must be reserved for a detailed paper on this subject.

To sum up the general results: the apparently mysterious action of iron on *Phycomyces* is nothing but a matter of hydrotropism; and hydrotropism itself (negative or positive) is the bending of a vegetable organ towards the points, not where it will find a minimum or maximum of moisture, but where it will, within certain limits, transpire most or least.

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5. *Notes on the Morphology of the Spore-bearing Members in Vascular Cryptogams.* *By* Professor F. O. Bower, *F.R.S.*

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6. *Notes on an Aposporous Fern Seedling.* *By* C. T. Druery.

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7. *A Chytridian Parasitic on Cyclops' Eggs.* *By* Professor M. Hartog, *D.Sc.*

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8. *On the Arrangement of the Buds in Lemna Minor.* *By* Miss Nina F. Layard.

The object of this paper was to illustrate the order of budding followed by specimens, the development of which was watched and figured by the writer, from that of a single frond until it had increased to a connected colony of six.

These observations seemed to point to the fact that this duckweed, as a general rule, produces two buds only, the first being usually from the right side, and the second from the left; though exceptions occur in both cases, and there are other difficulties which must be cleared away before any such law can be looked upon as established.

The following table gives the result of the examination of 475 duckweed groups taken from an outdoor aquarium on July 22, 1892:—

Single duckweeds	6	
Duckweeds in pairs	232	150 of which were bearing buds on the right side, and 82 on the left.
„ in groups of three	120	
„ „ four	92	
„ „ five	17	
„ „ six	7	
„ „ eight	1	
Total	475	

From this it would appear that the group usually breaks up when the fourth frond has been produced, thus explaining the comparatively few groups of five which are to be found. It would also account for the large number of pairs found during this month, and perhaps for the fact that there are more than twice as many pairs consisting of fronds with a right-hand bud as of pairs where the bud is on the left; for although the detaching of the right pair would temporarily leave a left-handed pair, this would soon be altered by the left young frond budding and pushing off the parent weed.

After other remarks upon the tethering filament which appears at the base of certain fronds in order to attach them loosely to the parent frond, and disappears shortly after they are separated, with an account of experiments with duckweeds grown in the dark, and others which continued to throw out buds, after being divided in half, the paper concluded with the following questions presented for the consideration of the botanical members of the Section :—

1. As to the number of buds produced by a single frond of Lemna minor?
2. The order and position of the buds?
3. The use of the connecting filament?
4. The absorption or destruction of the connecting thread after separation?
5. The explanation of the comparative number of fronds found connected, as shown in the table above?

Department of Physiology.

1. *Vital Absorption.* *By* Professor E. Waymouth Reid.

As a result of the researches of Dutrochet, the causation of the movement of fluids through membranes in the animal body was considered to be entirely due to osmotic action up till about the middle of the present century. The researches of Brücke, Liebig, Ludwig, Graham, Fick, Eckhard, and others, bear witness of the painstaking labour that has been spent upon the determination of osmotic equivalents and diffusion rapidities. It was found, however, that with variation in the kind of membrane used, and its state at the time of experiment, great variations in the results made themselves manifest. In 1845 was published by Matteucci and Cima a series of experiments with skins of frog, eel and torpedo, and various mammalian mucous membranes, in which it was shown that, provided the membrane was fresh, the direction of easier osmotic transfers varied with the facing of the membrane towards the solutions employed for experiment. and it was found that this peculiarity only existed so long as the membrane was perfectly fresh.

Later experiments with the bladder by Susini, using potassium ferrocyanide, and Cazeneuve and Livon, using urea, have shown how greatly the phenomena of diffusion through the wall are effected by the state of the lining epithelium. Tappeiner's experiments upon the absorption of bile salts from the dog's intestine, and those of Lannois and Lépine upon the absorption of glucose and peptone, have pointed clearly to the fact that the phenomena of intestinal absorption receive no clear explanation upon the old osmotic hypothesis.

Still more recently in Heidenhain's laboratory the work of Röhmann, and also that of Gumilewsky, has done more to show the necessity of discarding the physical explanation that so long seemed to meet the conditions of the case.

The consideration, too, of the changes that are wrought upon substances in process of absorption, such as the regeneration of albumen from peptone, pointed out by Salvioli, Hoffmeister, and Neumeister, and the synthesis of fat when fatty acid is supplied, demonstrated by Immanuel Munk, forces us to view the phenomena of absorption in the organism from the vital and chemical rather than from the purely physical standpoint.

Three years ago, in experiments directed to determine how far the physiological condition of a membrane can affect the magnitude of an ordinary osmotic stream caused to pass through it, I found, when using the skin of the frog freshly removed,

and taking precautions that the fluids in contact with it should have as little deleterious action as was possible under the conditions of the experiment, that the direction of easier osmotic transfer was from the outer towards the inner surface, the reverse of the direction of easier filtration in dead skin as demonstrated by Cima.

Contrasting, too, the action of fluids tending to preserve tissue life with that of those tending to destroy it, I found that while the skin was more permeable from without inwards so long as the fluids employed did not kill its tissues, yet so soon as a fluid was used that tended to destroy life, as, for instance, pure water, that then the direction of easier osmotic transfer was that of easier filtration in dead skin, *i.e.*, from within outwards. I concluded that a vital absorptive action existed in the living skin, by virtue of which it was able to aid the osmotic stream if such stream were passing in the direction from without inwards, for in such case the vital and physical stream would be in the same direction. If, however, the osmotic stream were passing in the direction from within outwards, being then contrary to the direction of the vital current, it would undergo a retardation. This hypothesis was much strengthened by the action of stimulant and depressant drugs upon the magnitude of the osmotic current through the living skin. A stimulant, such as weak alcohol, was found to increase the magnitude of a stream passing from without inwards, *i.e.*, in the normal direction of absorption; while, on the other hand, it diminished that of a stream caused to pass from within outwards, for here the opposing vital action was against the physical stream, while in the former case it had been with it.

Using chloroform as a depressant I obtained exactly reverse effects; with this substance a stream set up from without inwards was diminished, while one passing in the reverse direction was increased.

The crucial test of the hypothesis of vital absorptive force is to place exactly the same fluid upon either side of a living membrane, and to obtain evidence of transference of fluid across it in the normal direction of absorption in the body. This I have succeeded in doing with the skin of the frog by means of a special apparatus. I have suspended the skin between two layers of *baudruche* soaked in normal saline solution, and have seen a stream of normal saline pass across from the outer to the inner surface. With dead skin no such effect occurs, but only imbibition at both surfaces. This action does not appear to be of electro-osmotic origin.

With the intestine of the rabbit it has also been found possible to demonstrate vital absorptive action. Here the same apparatus and method have been employed as in the experiments with the skin of the frog. It is necessary for success that the loop of intestine selected for experiment shall be *in full digestive activity* as judged by the state of its lacteals, blood vessels, and contents. Here, again, with normal saline on either side of a piece of exsected gut, it is possible to get evidence of a stream passing from within outwards so long as the tissues are alive. Scraping off the epithelium diminishes the transfer or puts a stop to it.

Furthermore, by adding pilocarpine to the fluids used it is possible to reverse the direction of the stream, so that instead of a current passing from within outwards one may artificially produce one passing from without inwards; in fact, a piece of absorbing mucous membrane may have its action swamped by the induction of an excess of secretory action.

It is claimed for these experiments that they are *positive as regards the occurrence of vital absorption instead of merely negative as regards osmotic absorption*, as has been the case with the results of previous observers.

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2. *On Animal Heat and Physiological Calorimetry.* *By* Professor Rosenthal, *of Erlangen.*

To measure the amount of heat given out by a living animal is very difficult, because the common water calorimeter is not suitable for this purpose. Professor Rosenthal therefore chose the air calorimeter, first invented by Scharling and

recently adopted by D'Arsonval. He described shortly the apparatus constructed by himself, and gave a brief account of some of the results he obtained by his experiments. These extend to the heat-production in different conditions of the normal state and of fever. As to the latter, he found that heat-production is not augmented in fever produced by injection of putrid matters. But in a few experiments he made on men he found a small augmentation; and so he thinks that there are two types of fever with different causes of rising temperature.

Among the other objects of his investigations he principally mentioned the connection between nutrition and heat-production. According to his researches there is no strict proportion between the two, because the mixture of materials burnt in the body changes from hour to hour. After a rich meal the heat-production rises to a maximum point, falls then very rapidly, and is nearly constant between the thirteenth and twenty-fourth hour. It is nearly the same with the expiration of carbonic acid. But the changes of both functions are not quite proportional to each other. The expiration of carbonic acid rises more quickly, and reaches its maximum point earlier. So the ratio between both functions varies. And this is also the case in animals differently nourished, and in cases where heat-production changes in consequence of variations of the outer temperature or of muscular action. The combined investigation of heat-production and of the expired carbonic acid enables us to understand better the chemical processes going on in the system. The changing ratio between both shows that the mixture of materials oxidised in the body varies from hour to hour. Therefore it was impossible to find a strict accordance between heat-production and excretion until the new method enabled one to measure the heat produced during long periods of time, and to show exactly that animal heat also is produced only by oxidation, and that the law of the conservation of energy is true for the living body as in all other cases of combustion.

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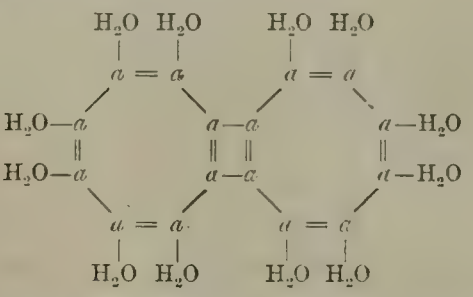
3. *Proteid Hydrochlorides.*

By A. Lockhart Gillespie, *M.D., C.M., F.R.C.P.E.*

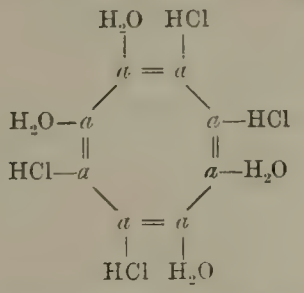
In applying this name to the *gebundene Salzsäure* of the German writers, the author seeks to accentuate the part proteids play in the combination. His views with regard to them are as follows:—

All proteid substances have an affinity for hydrochloric acid. The lower proteids in the series combine with a greater percentage of HCl than the higher. The percentage varies from 9 per cent. in the case of acid albumen to 18 or 20 per cent. in peptone. The greater affinity which the lower proteids have for hydrochloric acid compared with the higher may indicate the mode of their formation. If $-\overset{|}{a}=\overset{|}{a}-$ were considered to be the primary proteid molecule, the ultimate composition of which may be at present disregarded, but which is quadrivalent, serum albumen would be:—

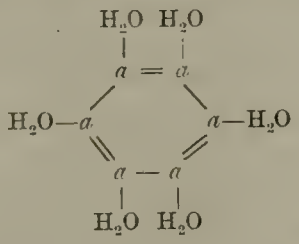


Acid albumen would be formed by the substitution of six molecules of HCl for six molecules of water. If more HCl combined, in the presence of pepsine,

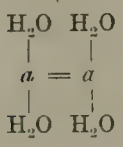
the molecule would split into two molecules of proto-albumose, each having the composition



Washing this with alcohol and then redissolving in water would give pure proto-albumose, water molecules taking the place of hydrochloric acid. In like manner deutero-albumose might be



and peptone



These relative proportions are supported by the amount of silver which is contained in a series of the different proteid compounds with silver, the various proportions being roughly (not sufficient data are yet to hand to allow of exact deduction) :—

Silver to albumen	. . . . .	1 to 8
„	proto-albumose	1 to 4·4
„	deutero-albumose	1 to 3·15
„	peptone	1 to ·75

The relative proportions of proto-albumose to that of deutero-albumose in these silver combinations are exactly paralleled by their respective rapidity of diffusion.

Proto-albumose diffuses more slowly than deutero, the exact figures being :— ·75 of proto-albumose dialyses in the same time, if under the same circumstances, as one of deutero ; while one part by weight of proto-albumose combines with silver for every ·72 of deutero.

This process of saturation of the proteid molecules, and their splitting up under the influence of HCl and pepsine, are of great importance in natural gastric digestion, and point to the reason why, in the early part of normal digestion, all the simpler forms may be found. Indeed, before ten minutes have elapsed after a meal which has included proteid substances, peptones may be identified in the stomach contents.

The different stages of gastric digestion after a meal consisting chiefly of proteids may be divided into—

1. Amylolytic stage.—Acidity slight, rising ; no free HCl present, but some combined with proteids. Duration, about ten minutes ; peptones generally present.

2. Combined hydrochloric acid (proteid hydrochloride) stage.—Acidity considerable, rising ; all forms of proteids present ; no free HCl ; probably some lactic acid. Duration, until about the half-hour.

3. Free hydrochloric acid stage.—Acidity still increasing; some free HCl, mostly combined; lactic acid disappearing. From the half-hour to three hours or so.

4. The chief absorption stage.—Acidity falling, but proportion of free to combined HCl rising. From third to fourth or fifth hours.

5. Evacuation.—Propulsion of contents into duodenum at fourth or fifth hours.

Summing up, the higher proteids may be compound molecules formed by combinations of different numbers of a primary proteid molecule, which probably is identical with the lowest proteid in the series. The compound molecules are split up into simpler forms by saturation with HCl in the presence of pepsine, the combination of the two evolving sufficient energy to effect this.

The reappearance of albumen in the walls of the stomach during absorption may be a reversed process, consisting of dehydration and consequent attachment of the lower proteid molecules together by the links thus left open.

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4. *On the Structure of the so-called Hibernating Gland in the Hedgehog.* *By* E. W. Carlier, *M.D., B.Sc., F.R.M.S., &c., Senior Assistant to the Professor of Physiology in the University of Edinburgh.*

This organ is a lobulated, bilateral, brownish-yellow structure, situated chiefly in the axillary, thoracic, cervical, and dorsal regions. It derives its nervous supply from the cutaneous branches of the cervical and upper intercostal nerves, in connection with which a ganglion is developed in the axillary region. Its vascular supply is obtained from the corresponding branches of the cervical and intercostal arteries, and from the inferior thyroid artery.

The organ is quite distinct from the thymus gland, though its cervical lobes come into intimate relation with the latter.

The size of the organ varies with the period of the year; it attains its maximum dimension in October, *i.e.*, just at the commencement of hibernation, and its minimum shortly after the animal has awakened from winter sleep.

Each lobe is surrounded by a fibrous capsule, from which septa pass inwards, dividing it into lobules; in these septa the blood-vessels and nerves ramify. In the fully formed organ the lobules consist of rounded or polyhedral cells of varying size from 23 μ to 34 μ in diameter; each cell consists of a granular mass of protoplasm exhibiting a fine wide meshed protoplasmic network, interrupted here and there by droplets of fat that vary considerably in size in different cases; in the centre of the cell is a spherical nucleus measuring 5 μ to 7 μ in diameter, so rich in chromatin that the contained nucleolus is almost invisible in stained preparations. The cell is surrounded by a definite though thin cell wall. A few cells contain two nuclei. The cells appear to arise at the margins of the developing lobules from small granular, unnucleated connective tissue corpuscles, which divide again and again, similar in appearance to those that give rise to adipose tissue generally. These cells gradually enlarge, their protoplasmic network becoming more and more distinct; presently tiny droplets of fat make their appearance at different points in the cell, which go on increasing in size with the growth of the cell, and which may or may not run together to form large fat droplets. The fat, however, never increases to such an extent as to completely fill the cell, a large part of the protoplasm, usually the peripheral portion, always remaining altogether free from it; the nucleus, around which most of the droplets are irregularly arranged, remains in the centre of the cell. Owing to the increase in size, the cells which are at first rounded become polyhedral from mutual pressure. The cells are always readily distinguishable from ordinary fat cells, of which many may be developed in the fibrous capsule of the organ.

Parallel with the increase in number and size of the cells there is an increase in the capillary blood-vessels, which multiply to produce a rich plexus between the cells, much in the same way as in adipose tissue generally. The veins accompany the arteries in their distribution. The ganglion found in connection with the axillary part of the organ consists of small closely packed unipolar nerve cells

similar to those of peripheral ganglia generally, except in that they possess no special envelope lined by endothelial cells. It is worthy of note that the large arteries of the organ exhibit a fine nerve plexus between their middle and internal coats, similar to and directly continuous with that ordinarily described between the middle and outer coats of larger blood-vessels generally.

If the organ be examined in March, *i.e.*, towards the close of hibernation, many of the cells will be seen to exhibit remarkable changes.

These changes appear to start in the nuclei, which begin to swell, assume a more completely spherical shape, lose some of their chromatin, and so reveal certain changes in the nucleolus which can now be seen to contain one or more colourless endo-nucleoli; from this nucleolus there are given off from time to time para-nucleoli, which pass gradually towards the periphery of the nucleus, meanwhile increasing in size, and presently find their way through the nuclear membrane into the surrounding protoplasm, where they break down and disappear; as the nucleus becomes more and more devoid of chromatin more of these bodies are produced, only one or two at a time, however, which, after piercing the wall, break down in the protoplasm; finally, the nucleolus itself passes towards the periphery of the nucleus, applies itself to the nuclear membrane, causing it to bulge somewhat at one point, through which it eventually passes into the surrounding protoplasm, to break down there just as the para-nucleoli have already done. After the passage through it of the nucleolus, the nuclear bag, still containing a few strands of chromatin, collapses and finally also disappears.

Whilst these changes are going on in the nucleus, the fat stored in the cell is gradually absorbed, and eventually entirely disappears; the cell wall disappears, and the protoplasm also exhibits changes; its network becomes less distinct, the finer strands seeming to give way, producing a finely granular appearance throughout the cell, amongst which a peculiar coagulable colloid-looking material may sometimes be seen which finds its way into the capillaries, and thence into the veins, where it appears in hardened preparations as a uniform hyaline mass with the red blood corpuscles imbedded in it. This material is not of the nature of glycogen, but possibly rather allied to lecithin. Eventually the whole cell disappears.

This change does not occur in all the cells simultaneously, but in groups of cells here and there, giving rise in those places in which it has been going on for some time to an appearance of greater vascularity, owing to the capillaries formerly separated by large cells gradually coming together as the intervening cell mass is absorbed.

By this process the very voluminous body present at the commencement of hibernation gradually dwindles away to almost nothing soon after the animal awakes from its winter sleep.

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5. *The Functions, Staining Reactions, and Structure of Nuclei.* *By* Gustav Mann, *M.B.C.M.*

The author holds the following views:—

1. The nuclear chromatin segments are organs for the transformation of simple into more complex compounds.

2. The nucleolus is a storehouse for material which has been elaborated by the nuclear segments.

These views are supported by the position of nuclei and nucleoli relatively to their cell walls and the supply of food, as seen in the vegetable kingdom in the sporangia of Tmesipteris, Selaginella, the embryo-sac of Angiosperms, &c.; and as readily demonstrated in the animal kingdom in the ganglion cells of the retina, during the development of the chick, in the alimentary canal of the salamander, &c.

3. The staining reactions of nuclei and nucleoli during their 'resting' and 'asexual' condition, during division and senescence, and during the period of 'sexual' differentiation may be represented thus:—

—	Nucleus	Nucleolus
During rest	Blue	Red
During division	Red	Absent
During senescence	Red	Red
In the ovum	Blue-red	Red
In the spermatozoon	Blue	?
In fungi	Red	Red

The following explanation is offered:—The nuclear segments being the organs for the elaboration of food and the nucleolus a storehouse for elaborated material, we must suppose that the new material which is being conveyed to the nucleus will take on a blue stain, because during senescence, division, and other conditions, when the cell may be supposed to be less actively assimilating food materials from without, we have invariably a red colouration taken on by the chromatin. This would also explain why the spermatozoon, owing to its great activity, is not able to lay up a store of elaborated material, and why it should stain blue, and why the nuclei of fungi living on elaborated material should stain red.

The view taken of the stainable material led of necessity to the belief that the achromatin of the cell is the essential plasma, and the latter really seems to play the most evident and important part during all phenomena connected with either division or conjugation.

Two special seats or centres of the achromatic substance may be recognised, one being the archoplasma, the other the endo-nucleolar substance. From the central endo-nucleolus, within the nucleolus, many delicate fibrils may be traced to the hyaloplasm of the cell, and tubular fibrils may be seen to pass from the chromatin segments to the nucleolus.

These observations made by the author on the nuclei of *Scilla nutans*, after fixing the ovules by his picro-corrosive alcohol, have been confirmed by M. Heidenhain in his elaborate paper on the leucocytes of *Salamandra maculata*.

Department of Zoology.

1. *On the Social Habits of Spiders.* *By* Dr. McCook.

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2. *On a Use of the External Ear.*
By Professor A. Crum Brown, *F.R.S.*

The form of the external ear is such that a continuous uniform noise is heard differently, both as to intensity and as to quality, when it strikes the ear at different inclinations. As binaural hearing enables us to determine the azimuth in which a source of sound is situated by turning round about a vertical axis until the sound is heard equally in both ears, so the form of the external ear enables us to find the altitude of the source of sound by rotating the head about a horizontal right and left axis until we hear the sound with a quality and intensity which we recognise as that of a sound proceeding from a source situated in the plane containing the lines of direct vision when these are in their mean position in reference to the head.

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3. *The Method of Comparative Psychology.*
By Professor C. Lloyd Morgan.

The object of this communication is to show that our interpretation of animal intelligence is necessarily based on a double or twofold process of observation.

First, the activities of animals have to be carefully observed as objective phenomena. Secondly, our own mental processes have to be carefully observed, and cautious inductions have to be drawn therefrom. Finally, the objective phenomena reached by the first process of observation have to be interpreted in terms of the conclusions reached through the application of the second process. Naturalists are too apt to forget that the second process is as essential as the first, and that to do good work in comparative psychology it is necessary to be a psychologist. Neither process of observation can be omitted if results of scientific value are to be reached, for both are of co-ordinate importance.

Psychological analysis is beginning to make clear the nature of the feeling and perception of relations. It also discloses that there is a well-marked contrast between (1) the mere feeling or practical awareness of relations, and (2) the definite perception or cognition of relationships. The former is the foundation of practical skill; the latter is the foundation of explanation and knowledge. The former is manifested in the simple psychical life of external perception; the latter involves introspection and reflection.

In the higher animals there is abundant evidence of ability to feel and respond to relations, and of wonderful practical skill based on direct experience. There is little or no evidence of the perception or cognition of the relations, of introspection, or of reflection. It is well to restrict the words 'reason' and 'rational' to the latter process. Animals are certainly intelligent; they may be rational.

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4. *On the Relationships and Rôle of the Archoplasmic Body during Mitosis in the Larval Salamander.* *By* J. E. S. Moore, *A.R.C.S. Lond.*

The existence of the 'Nebenkern' as a frequent cellular constituent has been pointed out by a variety of authors whose descriptions relate to vertebrates and invertebrates alike, but hitherto certain elements of confusion, arising from the simultaneous description of other bodies, obviously heterogeneous and foreign, have relegated this structure to a position of only secondary importance in cellular anatomy.

Our most accurate knowledge of the 'Nebenkern' is derived from Platner's admirable description of its origin and metamorphosis in the spermatocytes of *Helix*, where it plays so marked a part in the indirect division of the cell.

Hermann's more recent description of an archoplasmic body in the spermatocytes of the salamander, and his institution of a probable homology between this, the 'Nebenkern,' and the 'sphère attractive' of Van Beneden, renders the possible extension of these observations to other kinds of cells a matter of primary interest to those desirous of embracing under some more general formula the varied phenomena of mitosis.

The duplication of the spheres in *Ascaris*, as compared with the single archoplasmic body in the spermatocytes of *Salamandra*; the invariable appearance and relationship of a central body or bodies, of the 'medullary corpuscle' and outer 'archoplasm' in the former; and the frequent absence of 'medullary zones,' central body, or both, from the archoplasm of the latter, are considerations antagonistic to the desired demonstration of the above homology.

Much of this confusion is dispersed by discoveries in the embryonic genital ridge of the salamander. In this tissue the archoplasmic body is much more definite than in the spermatocytes, and may become duplicated, as in the 'sphères attractives' of *Ascaris*.

It presents a serial metamorphosis identical with that of the spermatocytes of *Helix*. During certain phases of this, the relationships of the central body, zone, and archoplasm are identical with those existing in the spheres of *Ascaris*.

The interest and significance of the above observations are greatly increased by the discovery of an archoplasm ('Nebenkern,' 'sphère attractive') in certain phases of the life history of the leukocytes in the same amphibian larvæ. The existence of the archoplasm ('Nebenkern') in the cells constituting the undifferen-

tiated genital ridge of the salamander shows that it is not specially related to the spermatocytes; while its appearance in cells so obviously primitive as the leukocytes proves it to be in no way specially connected with the reproductive elements, and suggests that it should be regarded rather as a normal constituent of the resting cell.

The 'attraction sphere' of Flemming cannot represent *in toto* those described above, as it consists of a central body (or bodies) and its immediate radiation only, apart from anything analogous to the definite archoplasm which Hermann describes. The complicated origin attributed to the spindle in the mutually irreconcilable descriptions of previous authors is, moreover, much simplified by the study of the cells in the same genital ridge. The intimate connection between the 'Nebenkern' and spindle described by Platner in the spermatocytes of *Helix* is most strikingly borne out during the metamorphosis of these cells. The central bodies become duplicated; the two halves recede from one another through the archoplasm, whose mass elongates in the direction of their motion.

The delicate external radii of the cell mass follow the central bodies as specific centres while *en route* to the polar extremities of the archoplasm; until, simultaneously with their arrival in this position, these radii assume the characters of the well-known astral radiations.

The whole spindle is formed from the intervening archoplasmic mass, and apparently from nothing else.

So soon as the constriction to form the daughter-cells becomes apparent, the expanded spindle fibres collect around the intermediate bodies of Flemming, and by their fusion regenerate an archoplasm on either side of the last division planes of the cells. The central bodies enter into a secondary connection with these new archoplasms, travelling up the fibres which remain between them and the concavities of the daughter nuclei. It thus appears that in these various cells of the vertebrate (*Salamandra*) Platner's generalisation with respect to the cells of the invertebrate (*Helix*), that 'zwischen Knäuelgerüst, Spindelfasern und Nebenkern ein genetischer Zusammenhang existirt,' is strikingly extended and borne out.

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5. *On an Abnormal Horse's Foot.* *By* Professor J. Cossar Ewart.

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6. *The Origin of Sex.* *By* Gustav Mann, *M.B., C.M.*[1]

While studying the origin of sex, two distinct points must always be kept in view—first, the origin of sexual cells; and secondly, the physiological cause determining the sex of potential sexual cells.

With Ryder and Hartog the author believes that sexual cells are derived from 'Zoosporangia,' as a common origin of male and female cells seems to be proved by the reduction in the number of chromatin segments which occurs in both male and female cells previously to the act of fecundation.

The author holds, further, that any condition unfavourable to a ready assimilation of food will produce a male organism; while, reversely, any condition favouring the assimilation of food will tend to produce a female organism.

Conjugation of two cells is, then, equivalent to the new-formation of one cell thus constituted, that a common trophic centre is formed which is capable of exerting its influence over the various organs, and that its organs are able to maintain the trophic centre by satisfying its chemical affinities—*i.e.*, its hunger.

The author does not believe, therefore, the active male cell to effect the restoration of the equilibrium, as manifested by the division of the passive female cell, by acting either as a ferment (v. Sachs), or by simply doubling the amount of chromatin in the female cell (Strasburger, Weismann, Ryder), or by being the carrier of katastates (Geddes and Thomson), or by restoring the susceptibility of the female nucleus to stimuli from its own cytoplasm (Hartog); nor have we digestion of the

[1] For a full account of author's views *see* 'The Embryo-sac of *Myosurus minimus, L.*,' *Trans. and Proc. of Bot. Soc., Edinburgh*, July 1892.

two cells, or isophagy, as Ralph believed, but feeding of the starving cell on the surplus nourishment of the overfed cell, with no digestion of the living achromatic plasm, whether this be in a non-specialised condition as endonucleolar or archoplasmic matter, or in the specialised condition forming the frameworks of the nuclear and other organs.

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7. *Larvæ and their Relations to Adult Forms.* *By* J. Beard, *M.Sc.*, *Ph.D.*

Starting from the fact that two common types of development have hitherto been recognised—viz., larval, with metamorphosis, and fœtal, or direct—the author attempted to show that all Metazoa above Cœlenterata developed through the intermediation of a larva, and, in fact, upon the latter. This was indeed known to be the case in a great many forms, and in others traces of a larva could always be detected. The great influences which led to the disguising of the larva were shown to be either the lading of the larva with food-yolk, or its acquirement of a parasitic life within the parent form. The former adaptation led to a loss of motor and some other organs on the part of the larva, while the latter tended to its degradation and degeneration, as in all fixed internal parasites.

Even in mammals traces of a larva might be met with in the amnion and yolk-sac placenta, and additional reasons were adduced for a belief that here also the development took place upon a larva. This was rendered more probable by the reflection that a fixed internal parasite never could and never did develop to a higher organisation, such as that which the mammal attained, but that the parasitic larva might become degenerated and yet give rise to the higher organism which developed upon it.

The researches of Kleinenberg (*Lopadorhynchus*) and Kennel (*Peripatus*) were cited, and their views on the mode of development of some invertebrates were stated to be in close agreement with those enunciated by the author.

It was urged that the recapitulation theory was no explanation of the phenomena of embryology—at best, it held good to a limited extent for the ontogeny of certain organs.

The views of the author led him to regard Metazoan development as a sort of alternation of generations.

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8. *The Exploration of the Irish Sea to the South of the Isle of Man.* *By* Professor W. A. Herdman, *F.R.S.*

SATURDAY, AUGUST 6.

The following Papers and Reports were read:—

1. *On a Myograph for the Projection of Muscle Curves, and on a Method of Recording the Time of Voluntary Movements.* *By* Professor John G. M'Kendrick, *M.D.*, *F.R.S.*, *F.R.S.E.*

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2. *On the Origin of the Electric Nerves in the Torpedo, Gymnotus, Mormyrus, and Malopterurus.* *By* Professor Gustav Fritsch.

The author directed attention to the organisation of the electric fishes, with the purpose of throwing some more light on certain general questions relating to the functions and structure of the elements in the nervous system.

There are two kinds of electrical organs found hitherto, one originating from modified muscles, as in Torpedo, Gymnotus, Mormyrus, and Raja; the other

belonging to the cutaneous system, most likely transformed gland-cells of the skin, which are found in Malopterurus.

In the nervous apparatus, to make these organs act according to the impulse given by the will of the fish, there are found in every instance wonderfully developed ganglion-cells, from which the impulse passes directly to the electrical organs. In all the cases where the electrical organs are of a true muscular character the ganglion-cells send out well-defined, not branched, axis cylinders, one from each cell, which may easily be traced into the anterior roots of the spinal cord or medulla oblongata. These cells are more or less plentiful just as the nerve fibres arising from them are.

In the cutaneous organs of Malopterurus there are only two ganglion-cells for innervation, one on each side, and only one nerve fibre belonging to each cell. That fibre does not rise from the cell-protoplasm as a true axis cylinder, but is formed by a combination of protoplasmic processes at a certain distance from the giant ganglion-cell. The electric current in the latter case has the opposite direction from that in the former.

It should also be kept in mind that in many other cases, not concerned with the electric fishes, peculiar ganglion-cells are found where peculiar functions of the nervous system occur. For instance, large ganglion-cells are found in the motor region of the brain, first seen by Betz, who looked for them on purpose to state anatomically the laws of localisation found by Professor Hitzig and myself—a branch of science which has been followed up in a glorious way by Professor Horsley, of London.

Inflammation and decay of motor ganglion-cells might cause spasms in the muscles belonging to them, as was stated lately by Professor Hitzig in a case of tetanus of the head, where the motor cells of the fifth nerve were found to exhibit marked vacuolation.

All these facts prove evidently that the ganglion-cells must be essential for sending on the nerve impulse to peripheral organs, and that the view recently put forward by Nansen, that the ganglion-cells are necessary only for the nutrition of the nervous tissue, is not the true one.

In Mormyrus there is another very important fact to be stated, which touches also the nature of functions in ganglion-cells. Besides the axis cylinders, the electric cells in the spinal cord send out broad processes, which communicate quite regularly on such a large scale that there cannot be any doubt that these cells form a complete system, being united for common work.

The axis cylinder being a well-defined, not branched, process, the other uniting processes must be considered protoplasmatic (in the sense of Deiters). Their frequent communications cannot have any other meaning than to warrant the equality of action in the electric shock. That statement being admitted, *the protoplasmic processes of the cells must be conducting structures.* If that is true in the Mormyrus, there is no reason whatever why it should be otherwise in the rest of vertebrate animals, although Golgi states that the protoplasmic processes are not nervous.

There is another proof in the organisation of Mormyrus regarding the same object of combined action in the electric organs on both sides. The upper as well as the lower electric nerves form a decussation outside the vertebral column, like a chiasma. As there is no other instance recorded that motor nerves cross over from one side to the other through the median plane of the body, this shows the immense power of adaptation to function (in the sense of Charles Darwin) which nature is apt to work out.

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3. *On the Leaf of Victoria Regia.* *By* Professor L. C. Miall, *F.R.S.*

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4. *The Blood-vessels and Lymphatics of the Retina.*
By James Musgrove, *M.D., Demonstrator of Anatomy, Edinburgh University.*

When we remember that the retina is to the eye what the sensitive plate is to the photographic camera, it need hardly be wondered at that nature has provided a

special set of vessels to bring to it a stream of pure blood, veins to remove the impure blood, and a third set of vessels, the lymphatics, concerned in preserving the retina in a state of healthy vitality.

The retina forms the innermost layer of the eyeball, and in shape is a hollow sphere with a hole in front to allow the rays of light to impinge against the posterior part of the membrane. It is this shape of the retina that has hitherto prevented its demonstration with the oxy-hydrogen lantern, owing to the difficulty of bringing the parts into one plane. This difficulty I have, however, overcome by carefully stretching the peripheral parts of the retina of the ox and other animals, and preparing as a lantern-slide.

As the central artery appears at the optic disc, it gives to the lower part of the retina from two to four branches. Of these branches two pass more or less horizontally, one going towards the nasal and the other towards the temporal side. From these two vessels branches pass right and left until the stem is exhausted. Those passing upwards from these two vessels pour their blood into a region which may be spoken of as the intermediate zone, where only capillaries are found. In addition to the inferior branches mentioned, there are generally two others passing downwards. These go to the lowest part of the retina. Occasionally they pass for a short distance as one trunk, which divides into two branches, to be distributed, one to the nasal and the other to the temporal side at the most inferior part of the retina. The veins accompanying these last two vessels are much larger than the arteries, draining the blood from a much more extensive field than is supplied by the arteries. After giving off these four branches, the main artery courses in an almost straight line upwards and outwards. Sometimes, however, it may be seen to be entwined around the corresponding vein once or twice. The main stem gives off two or three branches to the temporal side, and an equal number to the nasal portion of the retina, and sometimes terminates by dichotomous division. The first two branches given off (one on the temporal side, the other on the nasal) send twigs downwards to the intermediate zone already referred to. In nearly all cases the branches of the artery given to the inner or nasal side are larger than those to the outer side, since the inner part of the retina is larger in consequence of the point at which the optic nerve pierces the sclerotic in the ox.

When the specimens are shown on the screen with the aid of the oxy-hydrogen light, there is brought out very prominently the fact that, as regards the distribution of vessels, the retina may be divided into three parts—a lower portion containing branches of the four arteries and veins already described, an upper part containing also large vessels, and an intermediate zone entirely free from large vessels except in so far as it is traversed by the main stems of the artery and vein in their course to the upper part of the retina. This intermediate zone appears on the screen as a wide belt, not unlike a 'watershed' in appearance, but when examined under the microscope, the part occupied by capillaries only is much narrower than it appears on the screen. This zone would seem to be the homologue of the yellow spot found in the human retina.

Under the microscope, there is seen, throughout the whole extent of the retina, to the very margin of the membrane, a dense capillary plexus. The capillaries immediately associated with the arteries differ from those directly connected with the veins in that they form irregularly shaped meshes, with the appearance of a confused network, whereas those pouring their blood directly into the veins have more regularly rhomboidal meshes, and show a general convergence towards the vein in which they terminate.

In addition to the specimens described, I made preparations of the injected retina for vertical sections, and found that the vessels lay chiefly in the nerve-cell layer, the inner molecular layer, and the inner nuclear layer. Only rarely were capillaries found beyond the inner nuclear layer, and they never extended as far as the outer nuclear layer, so that the outer layers of the retina are entirely free from vessels.

From the foregoing account it is apparent that the retina, far from being a membrane with a few vessels only, as might be inferred from ophthalmoscopic examination, is permeated throughout its whole extent by a dense capillary plexus.

5. *Remarks on a Series of Extinct Birds of New Zealand, recently discovered.* By H. O. Forbes, *F.Z.S.*

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6. *Natural Relations between Temperature and Protoplasmic Movements.* By Jas. Clark, *M.A., Ph.D.*

For every vegetable cell showing streaming movement in the protoplasm there is a minimum temperature below which all movement ceases, an optimum at which the rapidity of the streaming is greatest, and a maximum beyond which movement is impossible. Of these the minimum is of greatest practical importance.

Although we possess many isolated determinations of the minima for various plants, no attempt has yet been made to carry out a series of systematic observations on the subject.

As might have been expected, the minimum varies greatly according to the nature and the general surroundings of the plant. Thus, of eight species collected on the Vincent pyramid of Monte Rosa at a height of over 10,000 feet all showed streaming movement in the parenchyma of the stem at 0° C.; of six collected at a similar height on the Aletschhorn five gave identical results, the exception being *Linaria alpina*. The plants, too, that flower on the lower Swiss Alps immediately on the retreat of the snows in spring—*Soldanella alpina*, *S. pusilla*, *Crocus verna*, *Primula integrifolia*, *Alchemilla pentaphyllea*, &c.—all exhibit decided protoplasmic movements at 0° C. Similar results are obtained from winter seedlings of *Stellaria media*, *Cerastium triviale*, and *Senecio vulgaris* in England. The stem parenchyma of most of our farm crops gives a minimum of about 5° C.; for sainfoin (*Onobrychis sativa*), Lupines, Indian corn, the minimum is from 8° C. to 11° C.; for tomatoes about 14° C.; and for the majority of stove plants 18° C. or over.

Such minima are not constant for the same species, but vary according to the conditions under which the individual has actually been growing. *Cochlearia officinalis*, growing on our sea coasts, usually gives a minimum of 5° C. to 7° C., whereas the minimum for specimens collected on the Horneckalp in the Justisthal was about 1° C. *Asphodelus albus*, on the Riederhorn and at Rawyl in Switzerland, shows a minimum of 2° C., and in its Mediterranean habitats of 7° C. to 11° C.

The minimum for the stem parenchyma of *Soldanella alpina* is usually 0° C. or lower, but there is a variety found on the lower slopes of the Rigi in which the minimum lies between 5° C. and 7° C.

Seeds of *Androsace glacialis*, *Anemone vernalis*, *Cherleria sedoides*, *Draba Wahlenbergii*, *Gentiana bavarica*, var. *imbricata*, *G. nana*, *Saxifraga bryoides*, &c., collected at a height of 8,000 feet or more, produced plants in the botanical gardens at Tübingen and in the vicinity of the Lake of Geneva, in which the minima were from 4° C. to 12° C. higher than in the parent plants. Seeds from these garden-grown plants, though capable of germinating freely on the plain, rarely did so when sown in the habitats of their mountain ancestors. Specimens of *Potamogeton marinus* from Lake Fully (7,000 feet) showed streaming movement in the leaf at 0° C., but, on being kept in the botanical gardens at Tübingen for six months, showed a minimum of 7° C.

In the marshes of the Jura, where, in consequence of local conditions, the average temperature is very much lower than that of the surrounding country, the minima for protoplasmic movements in the stem, and particularly the root, are very low. In the parenchyma of the roots of *Gentiana pneumonanthe* and *Swertia perennis*, for instance, circulation of the protoplasm was well defined at 0° C., and in the upper part of the stem was just visible at 2° C.

The minimum for the cells of the root is, as a rule, lower than for those of the stem and leaves, the difference in some bog plants examined being as much as 8° C.

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7. *Experimental Observations on the Function of the Nucleus in the Vegetable Cell.* *By* Jas. Clark, *M.A., Ph.D.*

When certain cells are immersed in a 10 to 20 per cent. solution of cane sugar a plasmolytic shrinking takes place in the protoplasmic contents, and it often becomes possible with careful manipulation to strip away the cell wall and leave the rest of the cell intact. When this has been done in the case of *Spirogyra* and *Nitella*, and of cells from the leaf of *Funaria hygrometrica*, *Elodea canadensis*, and *Vallisneria spiralis*, a new cell wall as a rule appears. When the nucleus is eccentric the new cell wall makes its first appearance in the proximity of the nucleus and gradually spreads over the whole of the protoplast. In *Spirogyra*, for instance, if the nucleus be in the centre of the cell, the new cell wall first appears as a girdle round the middle of the somewhat elongated protoplast; if the nucleus be at the side, then cell-wall formation begins as a rule at that point on the outer surface of the protoplasm nearest the nucleus, and for a variable time cell-wall formation is confined to that side of the protoplast where the nucleus happens to be.

Slight mechanical irritation of the protoplast in *Spirogyra* at a point near the nucleus hastened the formation of the cell wall; or, if the cell-wall formation had already begun, caused an increasing thickness in the same. Similar irritation at a point remote from the nucleus caused protoplasmic contraction and reduction in the complexity of the protoplasmic movements in the neighbourhood.

By purely mechanical means it is possible, by compressing the cell wall, to divide the contents of a cell of *Spirogyra* and various other plants into two equal parts completely separated from each other, the one half containing the nucleus, the other not. The part containing the nucleus functionates exactly as an ordinary cell, but is, if anything, more active. In the case of *Spirogyra* it can form a new cell wall, and many, by repeated cell division, grow into a new and independent filament, provided the old cell wall be torn to allow its escape. When submitted to slight mechanical irritation the nucleated portion usually passes into a resting stage. In *Spirogyra* the part without the nucleus is capable of forming starch, occasionally in abundance; and the protoplasmic movements usually undergo extensive simplification, well-marked circulation being at times converted into rotation. When protoplasmic movements are arrested in the non-nucleated portion by the withdrawal of oxygen, they are not restored by the introduction of a normal oxygen supply.

When the tip of a very young root-hair of *Trianea bogotensis* is separated from the basal nucleated portion the nucleus advances towards the place of separation, where the formation of a new layer of cell wall occurs. The nucleus then returns to its original position and the hair resumes ordinary growth. In a hair so treated the characteristic fountain-like rotation never subsequently appears, though in other respects the hair may be quite normal.

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8. *Co-ordination of Cellular Growth and Action by Physical Forces.* *By* Francis Warner, *M.D.*

Referring to former publications, the author points out the importance of studying cellular action, and the attributes, time, and quantity of action, in each elemental part of the object observed; this is particularly needful in studying the brain. Generalisations from observation of cellular growth are formulated, with references to examples of control by physical forces. Co-ordination of growth and of nerve-action is alike due to control of the attributes (time and quantity) of the elemental parts of the organism, leading to proportion and form of growth, and order of nerve-action; both supply of pabulum and stimulation may bring about such co-ordination.

In children normal proportional growth and normal nerve-action have been shown usually to coincide.

Evidence is advanced that 'similar living things under similar conditions of

environment—*i.e.*, supply of pabulum and stimulation by physical forces—tend to subsequent similar action.' From the study of growth, movement, and expression of mental states, the author suggests that 'all vital phenomena occur in the parts of a living body; they necessitate not only supply of pabulum, but also stimulation by force; these conditions together are commonly called the environment, and are capable in many cases of determining a control leading to subsequent co-ordinated action.' It appears that when once a special combination, or group of ratios of growth of parts, has been established by the environment, it tends to recur, and may be easily reproduced or called into action.

The facts accumulated in a report on 50,000 children observed by the author appear to confirm these views, showing that defects in development of the body are largely co-related with defects of the nerve-system in its power of co-ordination and mental function.

A table showing methods of observation and description of living objects, the nerve-system in action, and conditions of children was appended to the paper.

MONDAY, AUGUST 8.

The following Papers were read:—

1. *A Sketch of the Scottish Fisheries, chiefly in their Scientific Aspects, during the past decade* (1882–1892). *By* Professor W. C. McIntosh, *F.R.S. L. and E.*

At the period with which the present survey begins the pelagic condition of the eggs of the food-fishes was little known to scientific men in Britain, though Sars and others had described this condition in the eggs of cod, haddock, and gurnard, while others had added the eggs of the pollack, bib, pilchard, mackerel, &c. The complaints of the fishermen in regard to the scarcity of sea-fishes caused the Government to appoint a Royal Commission about the commencement of this period (viz., in 1883) to inquire into the matter, with Lord Dalhousie as chairman. No statistics were then available to show whether the fisheries were really diminishing. It was known that larger boats, longer lines, and a larger number of men were engaged in the pursuit, so that, even though fishes were abundant in the market, it might be that the fishermen of to-day gathered them from a much wider area than in former times. Consequently the maintenance of an efficient supply might be coincident with an actual diminution. Moreover, shortly before this period beam-trawling by means of steam-vessels had been introduced into Scottish waters, and further complicated the question. The Commission sifted all the matters complained of as fully as was possible, and, after the lapse of seven or eight years, Professor McIntosh did not think that any change of importance can be made in their carefully drawn conclusions.

Shortly afterwards the Fishery Board for Scotland, acting on the authority obtained through the Commission, closed certain waters against beam-trawling—viz., St. Andrews Bay, Aberdeen Bay, and the Forth—and procured a small steam-vessel (the *Garland*) for scientific experiments, and especially to inquire whether beam-trawling is an injurious mode of fishing. Stations were arranged for in the various areas, and in 1886 a commencement was made.

In examining the elaborate statistics, carefully drawn up by the Fishery Board, on the trawling experiments of the *Garland*, the author varied the mode of drawing deductions from them; in short, they were handled as in the report for the Royal Commission, the fishes captured being divided into two groups—viz., saleable and unsaleable—and St. Andrews Bay, about which most is known, alone considered. Without going into detail, these statistics show considerable variation. In 1886 twenty-one hauls of the trawl gave 1,792 saleable and 1,186 unsaleable fishes, or a total of 2,978. In 1887 the same number of hauls produced 2,649 saleable and 5,525 unsaleable, or a total of 8,174, or more than twice the

number obtained in 1886, and no notice was taken of the very large number of plaice captured by the liners. In 1888 twenty-five hauls gave 6,219 saleable and only 594 unsaleable, and of the latter no less than 436 were dabs and 135 plaice. In 1889 thirty-five hauls of the trawl gave 6,026 saleable and 1,004 unsaleable, or a total of 7,030, a considerable diminution on the previous year. In 1890 thirty hauls produced 6,421 saleable and 2,247 unsaleable, or a total of 8,668. During 1891 [1] thirty-three hauls gave 3,672 saleable and unsaleable 1,661, or a total of 5,333.

These results were then contrasted with the condition of the bay in 1884, and the differences in regard to the fishes captured by the various kinds of trawl (large and small) pointed out. The bay in 1884 contained a very considerable number of fishes, notwithstanding that, so far as man could, it had been swept for many years by fleets of sailing trawlers and by liners, and for several years by large steam-trawlers. The closure of the bay has not been followed by the growth of teeming multitudes of flat and round fishes; but, as pointed out in the Trawling Report, the large flat fishes occur mainly in the offshore waters, the smaller forms migrating outward as they grow older. Conversely the pelagic eggs, larvæ, and very young are borne shorewards. In regard to the large captures of plaice by the liners, it was explained that, having undisturbed possession of the bay, three sets of lines are used, and special exertions made to procure bait. The local benefits of the closure to the fishing community are undoubtedly great.

The increase in our knowledge of the development and life-histories of the British food-fishes was then dwelt on, and a list of these, for the first time hatched and reared at the St. Andrews Marine Laboratory, was given, together with others, the eggs or young of which had been partially examined. Between fifty and sixty species of fishes had been thus studied. Moreover, last season the comparative number of the various kinds of pelagic ova had been examined on the different areas in which the *Garland* worked.

Another feature of the decade has been the agitation concerning mussels for bait, an agitation arising from the increased price and diminished production. The advantages of the bed-system of management were pointed out, and the failure of the bouchot-system mentioned.

The workers who have contributed to the increase of our knowledge of the development and life-histories of fishes at St. Andrews were next alluded to—viz., Professor Prince, Mr. Holt, Professor Burdon-Sanderson, Mr. Gotch, Dr. Scharff, Dr. Marcus Gunn, Professor Cleland, Messrs. Pentland Smith, Teviotdale, Corbyn, Collinge, and others.

The valuable work done by the Fishery Board was then noticed, both in connection with the *Garland* and other departments. Amongst those who have published contributions to the annual reports are Professors Ewart, Greenfield, and Stirling; Messrs. Duncan Matthews and Calderwood; Dr. Fulton (the scientific secretary of the Board), Dr. Fullerton, Dr. Beard, Dr. R. H. Mill, Dr. Gibson, Messrs. Hoyle and Ramsay Smith, Mr. Anderson Smith, and Mr. Thos. Scott.

Finally various suggestions were made for the improvement of the Scottish fisheries in regard to marine food-fishes, mussels, and fresh-water fishes.

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2. *On Sea Fisheries.* *By* Professor J. Cossar Ewart, *F.R.S.E.*

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3. *On the Destruction of Immature Fish, and a Discussion on Remedial Measures.* *By the* Staff of the Marine Biological Association.

Part I. *Introductory Statement.*
By W. L. Calderwood, *Director M.B.A. Laboratory.*

The various conferences which have been held by the National Sea Fisheries Protection Association, and by representatives of the fish trade alone, have all had before them the question of the depletion of our sea fisheries. It has, in point of fact, always formed one of the most important subjects under discussion.

[1] This year is available only by the courtesy of the Fishery Board for Scotland.

In considering remedial measures necessary to the proper preservation of extra-territorial fisheries, the conference have considered the question from only one point of view, viz., that of prohibiting the capture and sale of what are termed 'undersized' flat fish.

It is an undeniable fact that within recent years a market has opened for the sale of these small fish, and that, in addition to this, modes of fishing are allowed which, carried on in certain localities, tend to the destruction of many fish even too small for the market.

The outcry against such procedure is very ancient, and has in past years led to legislation in this country; and at the present day in France and Denmark fish are not allowed to be sold under certain sizes.

In England the Act 1 Geo. I. stat. 5, cap. 18, established the following sizes, the measurements being from the eye to the end of the tail:—

No Bret or Turbot	under 16 inches
No Brill or Pearl	,, 14 inches
No Codlin, Bass, or Mullet . . .	,, 12 inches
No Sole, Dab, or Plaice . . .	,, 8 inches
No Flounder	,, 7 inches
No Whiting	,, 6 inches

Subsequently (by 22 Geo. II. cap. 49) a relaxation was made in favour of undersized fish if caught by a hook. At a later date this exemption was repealed, but ultimately (by 33 Geo. II. cap. 27) turbot and brill were altogether exempted from the list of undersized fish.

Finally, the Sea Fisheries Act of 1868 (31 and 32 Vict. cap. 45) abolished all restrictions on deep-sea fishing. The agitation almost immediately recommenced, and has been mentioned continually in official reports up to the present day. The question is therefore not a new one, but rather the repetition of an old-standing grievance.

Mr. Fryer, Inspector of Fisheries to the Board of Trade, in his Fifth Annual Report (1891), after discussing the difficulties in the way of restricting the size of mesh in nets, particularly those used for shrimping, suggests that 'a simple prohibition of any method of fishing could be much more easily enforced than a regulation involving constant watching and measuring,' and further remarks: 'The application of this principle to extra-territorial waters by means of an international agreement, and the adoption of a regular system of closing and opening certain areas in rotation, would probably secure fuller advantages than could be derived from any other method of protection in this respect.'

I give this extract in passing, since it shows, although on an entirely different system, a proposition to deal with this difficult question which is regarded with favour by many.

I shall now give the conclusions arrived at by the conference held in February of this year in the Fishmongers' Hall, since they may be considered the most highly revised.

I shall then give reasons why, in my opinion and in the opinion of my two colleagues, Mr. Cunningham and Mr. Holt, these sizes are quite unsatisfactory.

By resolution passed on February 25, after discussion and reference to a committee on the previous day, the following sizes were determined on:—

Sole	10 inches
Turbot	12 inches
Brill	12 inches
Lemon Sole	10 inches
Plaice	11 inches

At the commencement I would point out that these limiting sizes were agreed upon by the majority of the members present at the conference merely because they were the sizes which appeared to them best for preventing the sale of very small fish, and thus preserving them until they have reached a fair *marketable* size.

In our estimation the framing of this resolution is of almost no value, since its only point of recommendation is that fish at, or above, the sizes given fetch a

better price in the market than fish which are smaller. It takes no account of the question as to whether or not these fishes have ever spawned, and so contributed to the natural supply or up-keep of their species.

Our contention, therefore, is that, in all resolutions in which the line between marketable and undersized fish is drawn, that line should be the one separating, at the same time, the sexually mature and the sexually immature fish; and, further, that no protective measure of the kind referred to can possibly be of any ultimate value unless the fish are protected till after their first spawning season.

Further, Dr. Fulton's investigations have shown that, taking flat fishes as a whole, females are much more numerous than males. A matter of equal, if not greater, importance is the statement that, without exception, males were found ripe at a smaller size than the females.

Thus Fulton's figures show that in 23 males and 45 females (taking the turbot as an instance) the average length in inches of males is 16·85, in females 20·83.

It would appear clear from these observations, which have been verified over and over again, that if any resolution dealing with the capture and sale of immature fish be based upon the sizes at which the females alone spawn for the first time, the smaller male fish, which are also less numerous, need not be taken into consideration, since in proportion they will be protected to a greater extent than the females.

This opinion is held by Mr. Holt, Mr. Cunningham, and by myself, but Dr. Fulton still inclines to include males.

The appended table is arranged so as to compare the results from the four districts mentioned, and includes also the sizes agreed on at the last fishery conference.

It is necessary to mention each district separately, since the sizes at which the various species become mature differ very considerably on the different coasts.

Name of Fish	North Sea	E. of Scotland	Plymouth	W. of Ireland	Conference
Sole . . .	12	—	10	12	10
Turbot . .	18	18	—	17	12
Brill . . .	15	16	—	15	12
Plaice . .	17 (15)	12	12	15 or 16	11
Lemon Sole .	11	8	8	8	10

The figures under heading E. of Scotland are from Dr. Fulton's reports, those marked North Sea from Mr. Holt's. The W. of Ireland figures are also furnished by Mr. Holt, but owing to a confusion in some of the records from which these were derived these sizes are given with some reserve.

It must be recollected that Dr. Fulton's figures include male as well as female fish.

The size of Plymouth fish are given in each case a little above that of the smallest specimens found mature, thus allowing for variation of individuals.

PART II. *On the Relation of Size to Sexual Maturity.* (i) *North Sea Grounds.* *By* ERNEST W. L. HOLT.

I append a series of tables in support of the size-limits prepared for this area, giving the results of the examination of a number of fish at what appear to be the critical sizes.

I have used the term 'immature' to denote fish in which the testes or ovaries show no signs of reproductive activity, and which, to the best of my belief, have not reproduced their species in any previous season.

In the case of most species I find little difficulty in distinguishing between immature fish and such as have already spawned, since in the case of the latter the

new crop of ova commences to mature as soon as, or even before, the old crop has been ejected. Moreover some of the old ova are invariably retained in the ovary, and their presence is perceptible even several months after spawning. In some species, also, the ovary, on maturing, grows backwards, and thus assumes new topographical relations which it never again entirely loses.

It has been suggested that confusion may occur between immature females and females in which the ovaries, having once fulfilled their function, have reverted to a condition of rest. I can find no evidence that the latter condition is ever realised—at all events amongst marine Teleosteans.

In distinguishing immature females from such as are just commencing to approach ripeness, I find the most easily recognised microscopical feature in the relative translucency or opacity of the ovum.

In immature fish the condition and size of the ova are not materially influenced by the size of the individual in any species, but at the first approach of sexual activity an opacity manifests itself, under the microscope, in certain of the ova, and brings about changes in the appearance of the ovary, which, after some experience, are easily recognisable by the naked eye.

The changes in the ovum which bring about this opacity are familiar to students of ovarian development.

Male fish being of comparatively small importance in the present connection I have not devoted much attention to the minute anatomy of the testis, but it presents certain well-marked external characteristics which serve to distinguish the different conditions.

The table of comparative size-limits suggests a close relationship between the absolute size of a species and the size at which maturity is attained by that species in different districts.

Rate of growth being doubtless related to absolute size, it must be presumed, in view of Cunningham's researches, that there is a constancy in the age at which maturity is reached in all districts.

Most of the observations embodied in the tables were made during the spawning season.

EXTRACTED FROM THE TABLES.

Common Sole.

Smallest ripe male	Largest immature male	Smallest ripe female
9 inches.	11 inches.	$10\frac{1}{2}$ inches.
	Largest immature ♀	
	12 inches.	

Turbot.

Smallest ripe ♂	Largest immature ♂	Smallest ripe ♀	Largest immature ♀
12 inches	14 inches.	18 inches.	19 inches.

Brill.

Smallest ripe ♂	Largest immature ♂	Smallest ripe ♀	Largest immature ♀
12 inches.	14 inches.	15 inches.	18 inches.

Plaice.

Smallest ripe ♂	Largest immature ♂	Smallest ripe ♀	Largest immature ♀
6 inches	15 inches.	$13\frac{3}{4}$ inches.	19 inches.

Lemon Sole.

Smallest ripe ♂	Largest immature ♂	Smallest ripe ♀	Largest immature ♀
6 inches	8 inches	10 inches.	12 inches.

(ii) *Plymouth District.* *By* W. L. Calderwood.

Extracted from the Tables.

Sole.

Smallest mature ♂	Largest immature ♂	Smallest mature ♀
8½ inches.	10 inches.	10 inches.
	Largest immature ♀	
	9 inches.	

Plaice.

Smallest mature ♂	Largest immature ♂	Smallest mature ♀
8 inches.	12 inches.	11 inches.
	Largest immature ♀	
	11 inches.	

Lemon Sole.

Smallest mature ♂	Largest immature ♂	Smallest mature ♀
7 inches.	?	7 inches.
	Largest immature ♀	
	7 inches.	

No immature males observed.

At Plymouth turbot and brill have become so scarce and expensive that I have only been able to examine a few. All were males, and therefore of little importance.

Mr. Cunningham considers 12 inches a better size for the sole. In other respects he appears to agree with the sizes I have suggested in the comparative table.

Part III. *The Protection of Immature Fish.*
By J. T. Cunningham, *M.A.*

I. The Limit of Size for each Species.

My researches have been directed more to the question of the rate of growth and to the age at which maturity is reached than to the size of specimens taken at sea.

I have found, in the case of the flounder, that of a large number of specimens reared in captivity none became ripe when one year old, although a few reached the size of the smallest mature specimens, *i.e.*, a length of 7 inches. In the second spawning season from that in which they were hatched a proportion, viz., 19 per cent., became ripe and spawned. The rest did not become mature at two years old.

The results of this research, which I wish to emphasise, are two.

(1) That an adult or sexually mature fish is at least two years old, and more probably three years, while an average sized adult is usually four years old or more.

The importance of this fact is that it shows how easily the supply of a valuable fish may be diminished by over-fishing. A turbot, for instance, produces a very large number of eggs, from which comparatively few larvæ safely pass through their metamorphosis, and even after this the young fish have to find food and escape enemies for three or four years more before they reach the average size of fish brought to market.

(2) That the size of the smallest ripe fish is not the only point to be considered in fixing the limit below which the young fish require to be protected.

Assuming that a fish ought not to be killed before it has been able to reproduce itself and leave progeny to take its place, it must be remembered that while one specimen of a female flounder which is 9 inches long may be two-and-a-half years old, and have already spawned once, another which is 10 inches long may be only one-and-a-half year old, and have never spawned at all.

The limit fixed should therefore, in order to exclude all immature females, be somewhat higher than the size of the smallest (ripe) females observed.

II. The Benefit of the Proposed Restrictive Legislation.

If the destruction of all fish which had not spawned at least once could be successfully prevented the benefit would be indubitable, and the permanent productiveness of the sea fisheries would be assured.

But it is by no means certain that the prohibition of the sale of fish below a certain standard will prevent the destruction of such fish. All that can be said is, that it may be hoped that when the sale of such fish is made illegal the trawlers will avoid catching them as much as possible, and when they do catch them will throw them overboard.

(1) Can fishermen avoid catching them by ceasing to fish in certain areas? Are the small fish especially abundant in certain places?

There is evidence in Dr. Fulton's reports and my own that young plaice, sole, turbot, and brill haunt shallow waters, and in summer occur close inshore. It is said that the young of these kinds haunt shallow *extra-territorial* water on the east side of the North Sea. I cannot speak of the North Sea, but I know something of inshore trawling for small fish, especially soles and turbot, and this mode of fishing would be practically stopped by the proposed legislation.

On the other hand, it has been proved that the young of the lemon sole, megrim (or sale-fluke), long rough dab, and witch are never found in shallow water or near the shore, but prefer deeper water even than the adults.

(2) Can fishermen avoid catching the young fish by enlarging the mesh of the trawl?

I think to a great extent they can. If the mesh at the cod end, at present 1½ inch square, were enlarged to 3 inches square, more small fish would escape; the net would not be so liable to be choked with débris, and so kill the fish.

It is probable that if the proposed legislation were carried out the men would enlarge the mesh of their own accord, if recommended to do so.

(3) When young fish are caught and thrown overboard, will they survive?

From Dr. Fulton's experiments and my own experience I think it is clear that a proportion of the fish will survive, and equally clear that a good many will be killed. This applies to deep-sea trawlers.

The proposed legislation would cause shrimpers and ground-seiners to throw back the young fish they had caught, and if this were done at once as soon as the net was hauled the young fish would survive.

III. Other Measures for the Maintenance of the Fish Supply.

It has been abundantly proved that a *close time* is absolutely no use, even if it were practicable.

But on the other hand *close places* may be of the greatest benefit.

If fishing could be prevented in certain defined areas where young fish congregate, those young fish would live in security to supply large fish in the future.

It might also be possible to prevent fishing in certain areas where full-grown fish are abundant, in order that these might form permanent reserves in which there would always be abundance of mature fish spawning.

It might further be possible to prohibit trawling for a given number of years on exhausted grounds, to give them time to recover their productiveness.

Such measures as these could only be considered by a permanent fisheries commission composed of experts, such as exists in France, a central commission for the whole kingdom, as distinguished from the district committees.

Part IV. (i) *On the Destruction of Immature Fish in the North Sea.* *By* Ernest W. L. Holt.

We have long been familiar with the fact that immature fish of valuable food-species are destroyed in dangerously large quantities.

From time to time efforts have been made to ascertain the conditions that govern such destruction and its approximate extent.

The earliest of these was the Scotch Trawling Commission, the carrying out of which was fortunately entrusted to Professor McIntosh, then, as now, our highest authority on the scientific aspects of sea fisheries, and his report may be regarded as the classic of the subject.

More recently Dr. Fulton has been able to give us much valuable information as to the distribution of immature fish on the various grounds accessible to the *Garland*, and my colleague, Mr. Cunningham, has dealt with the same subject in the Plymouth district.

The results attained by the Royal Dublin Society's survey of the west coast of Ireland fishing grounds appeared early in the present year, my reports being arranged as far as possible on the model of those put forth by Dr. Fulton.

From their very nature, however, none of the observations gives us any idea of the total amount of destruction that is actually caused by any one practical fishing industry on any one coast.

Indeed, beyond a few vague statements, made at fishery conferences, &c., we have only Dr. Fulton's estimate of the numbers of small fish captured (though not destroyed) by the small fleet of shrimpers in Solway Firth.

I propose in the present paper to give such observations as I have been able to make on the actual quantity of undersized fish that have been landed at the port of Grimsby during the present year.

I shall limit my remarks to plaice, turbot, brill, and soles.

Plaice.—As may be seen from the comparative table, I consider that 17 inches is the average size at which female plaice spawn for the first time, and, therefore, the biological limit between mature and immature fish.

On every North Sea ground with which I am acquainted a proportion of the plaice fail to reach that standard; but at present I shall confine myself to the discussion of fish landed *from those grounds where only small fish are to be found.*

Moreover I shall not make use of the biological limit, but shall use the term 'small' in the sense in which it is understood by fishermen and fish merchants.

The appended figures refer, therefore, to fish which are undersized in every sense of the word.

The quantity is certainly not exaggerated; indeed, it is probable that a number of boxes have escaped my notice altogether, whilst I have omitted from consideration numbers of boxes which, though containing chiefly small fish, have yet had a few fair-sized ones arranged on the top.

There were landed at the port of Grimsby—

During April	. . . . .	1,826	boxes of small plaice	
„ May	. . . . .	830	„	„ „
„ June	. . . . .	3,470	„	„ „
„ July	. . . . .	2,059	„	„ „
Total for the four months	. .	8,195	boxes.	

In addition 155 large packing cases of small fish, caught by Danish boats, were brought to Grimsby market by cargo steamers.

The sizes of fish in the above boxes range from 6 or 8 inches up to a maximum of 15 inches, but in the majority of cases do not exceed 13 or 14 inches, or very frequently even 12 inches.

A box of such fish contains about 300 fish, more or less, weighing about nine stone.

To be far on the safe side let us take 250 fish as the number in a box, giving us a total for Grimsby smacks of 2,048,750 fish, or in round numbers 2,000,000. In all probability the actual number is not less than 2,500,000.

The packing cases contain about 200 fish, which gives us a total of 31,000 fish, sent over per cargo boat by foreign fishermen.

Thus we have direct evidence that at the lowest possible computation the consignments of *exclusively small plaice* landed at Grimsby from April to July reached a total of 2,079,750 fish.

I do not know whether the numbers I have given will appear surprisingly large or surprisingly small.

In any case we have to consider that the fish landed at Grimsby represent only a tithe of those brought ashore by the whole of the North Sea boats.

As a matter of fact only a single small 'fleet,' of about twelve sail, has been working the small fish grounds from Grimsby during the present year.

Only one steam-trawler, so far as I know, has regularly worked these grounds, though a good many others have made occasional trips to them. The balance of boats bringing in small plaice has been made up by a certain number of sailing smacks, 'single-boating,' and working the small fish grounds with more or less regularity.

Now from Hull alone two large fleets, each of about 250 sail, have been on these grounds during the present fleeting season, as has also the large fleet from Yarmouth, Lowestoft, and Barking.

Certain of the Hull and Boston steam trawlers have also visited the grounds from time to time.

The grounds alluded to lie along the Dutch, German, and Danish coasts, off the islands of Terschelling, Schiermonnikoog, Nordevey, Heligoland, and Sylt, off the Horn Reef, and along the Danish coast as far north as Haustholm.

It may be said at once that the greater part of all these grounds lies outside the territorial area. Some of them are 14 or 15 miles from land, and in one case the small fish extend even 40 miles from the coast. At the same time the productive area of some grounds extends as close inshore as the vessel dare go.

Besides the small plaice landed, great numbers are caught, especially on the grounds last referred to, which are too small to meet even the modest requirements of the present market, and it may be assumed that as trawling is at present conducted nearly the whole of such small fish are destroyed.

Destruction by Foreign Boats.—Besides the large British trawlers, there are a certain number of small boats of Dutch, German, or Danish nationality which are engaged in the small plaice trade.

On the whole, I think the damage inflicted on the fishery in this manner is comparatively small, since the German and Danish boats are careful to return the fish which are too small for market uninjured.

Our own fishermen agree that the share taken by foreigners in the destruction of immature fish is insignificant.

The German steam trawlers appear to avoid the small fish grounds altogether.

Turbot.—Besides the small plaice, the grounds which I have been referring to yield large catches of turbot. The bulk of these are immature.

Thus in June the aggregate of thirty-one catches was 4,623 fish. The proportion of undersized fish amongst these was 82 per cent.

During July eighteen catches comprised 2,435 fish, the proportion of small being 69 per cent. The diminution is probably explicable by the fact that the inshore parts of the grounds, chiefly frequented by the very small fish, became less productive in that month.

A certain number of immature turbot occur on all grounds frequented by the species, but I found that the aggregate of fish in the market during ten days before the regular opening of the eastern grounds season comprised only 30 per cent. of small.

Brill.—Contrary to the statements that have been made on this subject, I find that the proportion of immature brill landed from the eastern grounds is entirely insignificant. It is not sufficiently recognised that the brill is a smaller fish than the turbot, and matures at a smaller size. Most of the immature brill which I have seen came from the Lincolnshire coast.

Soles.—I do not think that the proportion of immature soles now caught on the eastern grounds is a high one, though there is evidence that in former years, when the boats went closer to the shore, great numbers were destroyed.

There is a fishery, ostensibly shrimp trawling, in the Humber, and though the number of fish caught in this way is not large nearly all are immature.

The use of a fish-trawl in the Humber is prohibited, but it is possible that the law is frequently evaded.

Undoubtedly there is considerable destruction of immature fish, chiefly plaice, but also including other forms by the various methods of inshore fishing practised in the Humber, but I do not propose to deal with that subject here.

(ii) *On Remedial Measures.* *By* ERNEST W. L. HOLT.

Various measures have been put forward for checking the destruction of small fish and renewing the fish supply generally. They may be classified as follows:—

(1) Prohibition of sale or possession of undersized fish.
(2) Closing of grounds frequented by small fish.
(3) Regulations affecting size of mesh.
(4) Close seasons.
(5) Artificial rearing.

Of these various methods I am inclined to consider that the first is likely to yield the most important results, since its enforcement would practically carry with it the closing of the grounds on the eastern part of the North Sea, where, as I have shown, by far the greater part of the damage is done.

Indeed, I believe that the prohibition of sale or possession of undersized plaice alone, or at most of undersized plaice, turbot, and sole, would render these eastern grounds so unprofitable that they would be entirely deserted by trawlers.

It is absolutely necessary, however, that the size limits should be higher than those proposed at the Fishery Conference. Indeed, in the case of turbot and brill I cannot understand why a limit of 12 inches should ever have been proposed, since, as the number of turbot and brill below that size which are landed at Grimsby is quite insignificant, the matter is practically left in *statu quo*.

In the case of the plaice I do not consider that it is absolutely necessary that the limit of 17 inches should be enforced, although, as I have shown, that is the natural or biological limit.

A limit of 15 inches would be high enough for the purpose, since all but a very few of the fish on these eastern grounds fail to reach that size.

It is the certainty of being able to pay his expenses by the sale of these small fish that induces the trawler to visit these grounds, since the amount of other fish taken there is utterly insufficient for the purpose.

The grounds lying without the territorial limits could not be closed without international arrangement, and even if that could be attained I believe that it would be practically impossible for cruisers to watch the grounds, great part of which lies altogether out of sight of land. Indeed, I am not aware that they find the enforcement even of such restrictions as already exist an easy task.

I consider an indiscriminate closing of the territorial area altogether inadvisable, since the distribution of young fish in relation to this area is by no means the same on all coasts, being largely affected by physical conditions, chiefly those of declivity.

I agree with Dr. Fulton in considering that no restriction of the mesh can be alone efficient in protecting undersized fish, though no doubt some good can be done in that way.

Such restriction should, in my opinion, take the form of an alteration of the pattern rather than any great enlargment of the mesh. Thus it is my experience that by substituting a square mesh for that at present in use, or by simply turning the mesh across, so that the strain of the trawl meets with the greatest instead of the least possible resistance offered by the knots of the mesh, much less small fish are captured.

Further, since the loophole of escape, if any, presents itself to the fish in the cod-end of the net, the alteration need affect only that portion, and thus would entail the minimum of trouble and expense to owners of nets.

I have already suggested that when a spawning ground lies within the jurisdiction of fishery authorities, such part of it as best offers itself to the watchfulness of the authorities might advantageously be reserved as a sanctuary for spawning fish during the season, but I do not see that any other form of close season is practicable.

I do not know of any North Sea spawning ground that fulfils the above requirements, though some exist on the Irish coast, and probably on the west coasts of England and Scotland.

With regard to the culture of sea-fish it appears to me that we should concen-

trate our efforts on the more valuable kinds of flat fish, especially turbot, brill, and soles, since the results, if successful, would be of infinitely greater value than an increase in the supply of such forms as the cod. I do not, however, believe that any success we may attain in this direction will justify us in neglecting the protection of undersized fish.

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4. *The Food of Fish.* *By* W. Ramsay Smith, *B.Sc., M.B., C.M.*

This paper gives a summary of four annual reports made by Dr. Ramsay Smith to the Fishery Board for Scotland. The reports were made from materials collected by the naturalists of the Board. The paper deals only with the most important fish of the Firth of Forth and St. Andrews, and gives the results of the observations made there during four years, irrespective of stations and seasons of the year. The statistics are so extensive as to reduce the limit of the errors of observation to such an extent as allow general conclusions of a trustworthy character to be drawn now for the first time from those observations.

The species of fish and the numbers examined are as follow:—

1. Firth of Forth: Plaice, 1,205; lemon soles, 821; common dabs, 1,211; long rough dabs, 1,512; witch soles, 217; flounders, 75; gurnards, 726; cod, 727; haddocks, 874; whitings, 1,050. Total, 8,418.

2. St. Andrews Bay: Plaice, 726; common dabs, 567; long rough dabs, 94; gurnards, 407; haddocks, 132; whitings, 137. Total, 2,063.

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5. *Notes on Teleostean Development.* *By* E. W. L. Holt.

Various forms are dealt with in the paper, but the feature of chief interest was the description, for the first time, of the ovum and early larva of the turbot (*Rhombus maximus*). The ovum has a diameter of about 1·01 mm., that of the single oil-globule being about ·21 mm. The larva, which is hatched in about eight days, in summer, is characterised by the ventral position of the oil-globule, and especially by the extremely brilliant rust-coloured pigment. Black pigment is also present, but in less quantity.

The ova, which are pelagic in their early stages, display a tendency to sink at a variable period before hatching takes place; a condition which may throw difficulties in the way of the artificial propagation of this species.

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6. *The Effect of Sea Water on the Vitality of the Salmon Fungus.* *By* A. P. Swan.

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7. *On the Formation of Argenteous Matter in the Integument of Teleosteans.* *By* Professor E. E. Prince.

During larval life the integument of Teleosteans is of a very simple character, and consists of two layers, an ectodermal external layer (epidermis) in which an outer corneous layer can be made out, and an inner mucous stratum, the latter generally several cells deep and giving origin to enlarged mucous cells; while internal to the epidermis is the mesodermic layer or true cutis, out of which the scales are developed. Below the mesoderm layer the muscle masses occur. In many young bony fishes this mesoderm layer is represented by a stratum of granular plasma, which takes a deep tint in stained preparations; and it is limited internally by a thin layer of flattened cells in which large pigment corpuscles occur. In such diverse forms as the Gadoids, *Labrus*, *Anarrhichas*, &c., this layer of granular plasma is well marked, and in it the fibrillated substance is formed to which the integument of many fishes owes its silvery lustre. In the mackerel midge, now known to be the small post-larval stage of certain species of *Motella*, this deposit of fibrillated matter is noteworthy. In a specimen $\frac{5}{16}$ in. long its

thickness is greater than that of the other layers of the integument, and in an example $\frac{7}{16}$ in. long the deposit of silvery matter is so great as to form a layer along the sides of the trunk five times the depth of the epidermis external to it. In the species named the silvery matter is very precociously developed, and the presence of long spindle cells amongst its fibrous strands suggests that it may arise from the lengthened cells of the deeper layer of the dermis. If not, then it is merely a fibrillated condition of the mesodermic plasma, in which stray cells of the dermis occur. This peculiar matter arises below and independent of the scales which are formed as protrusions of the outer dermal layers.

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8. *The Development of the Pharyngeal Teeth in the Labridæ.* *By* Professor E. E. Prince.

The wrasses are all characterised by the presence of toothed grinding plates in the pharynx. Below the pharyngeal epithelium, which is six or seven cells deep, the mucous layer cells form rounded dental sacs in which four distinct portions can be distinguished at an early stage, viz.: (1) an enclosing layer of flattened cells; (2) a single layer of nucleated round cells; (3) a columnar layer of enormous gland-cells, each with an eccentric nucleus, and secreting at the lower or proximal end a clear homogeneous substance, similar to the osteoid matter, which largely clothes the skeletal cartilages of post-larval Teleosteans; (4) a papilliform mass of rounded cells, representing the pulp-cavity of typical teeth. The last-named layer secretes a granular substance which stains deeply, and constitutes an inner cone of the developing tooth. This inner cone is soon covered with a clear coat of osteoid matter, except at the acuminate tip, and the large gland-cells are active in forming the clear non-staining matrix. The tooth lengthens, and by the time that it pierces the pharyngeal epithelium it forms a lengthened conical structure of clear matter, enclosing in its upper half an inner deep-staining cone which continues into the apex. Where the inner stained cone ceases a thickened stained band occurs encircling the whole tooth. Compound teeth occur with two or more pointed projections, and at their bases the teeth become attached below to the basi- and hypo-branchial cartilages and to the epibranchials above. The mucous layer of the pharyngeal wall is crowded with dental sacs at various stages of development.

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9. *On the Skin of the Hedgehog.* *By* E. W. Carlier, *M.D., B.Sc., F.R.M.S., &c., Senior Assistant to the Professor of Physiology in the University of Edinburgh.*

Skin of Dorsal Surface.—When the spines are clipped off, the skin is seen to be of a dull leaden colour and very rugose; the spines spring from depressions between the rugosities. The skin is very firmly attached to the sub-dermal structures.

On section it is seen to consist of a thick layer of dense fibrous tissue thrown into irregular elevations, over which a very thin epithelium is evenly arranged, which also passes downwards to form the sheaths of the spines. Beneath the fibrous tissue is a skin muscle of some thickness. There are neither sweat nor sebaceous glands in connection with the spines, but often a great development of adipose tissue beneath the muscle.

The epithelium exhibits only two layers, a stratum corneum of little thickness, and a rete Malpighi only two or three cells in vertical extent. The stratum lucidum and stratum granulosum are both absent. The mucosa consists of thick wavy bundles of connective tissue, with which are mingled near the epithelium considerable numbers of pigment cells. There are few blood-vessels in this dense tissue, but a free percolation of lymph.

The panniculus carnosus consists of striped muscle of the usual type, and is often of great thickness.

The spine follicles are situated in the cutis vera, and are of large size. The

thin neck of the spine soon widens out into a hemispherical root, the convex internal aspect of which is indented by a small vascular papilla. The sheath of this root consists of epidermic and of dermic coverings; of the latter nothing need be said; the former presents two layers, an outer and an inner root sheath, which is not subdivided into several layers of cells. A large fan-shaped arrector pili muscle is attached to the dermic coverings; it consists of non-striped fibres firmly attached, for the most part, to the deeper layers of the rete mucosum. In the neighbourhood of the spine is a fine capillary plexus; there appear to be no special nerve end organs, though tactile impulses are conveyed in some way from the spines to the brain.

The ventral region gradually passes into the dorsal at the sides of the animal. The skin is much thinner, less rugose, and less firmly attached to subjacent structures than that of the dorsum; it is covered with hair, and contains both sweat and sebaceous glands.

The epithelium is similar to that of the dorsum.

The cutis vera is thinner and finer than that of back, very vascular, and contains much adipose tissue.

The panniculus carnosus of striped muscle is thin, and exhibits some fibres in a more or less embryonic condition.

The sweat glands, situated deeply in the cutis vera, are lined by a single layer of cells surrounding a central lumen; the non-striped muscle fibres between them and the basement membrane are inconspicuous or wanting. The ducts are lined by a single layer of cells.

The hair follicles are similar to those of other animals; the arrector pili muscle and sebaceous glands are large.

Hairs and Spines.—The hairs are of the fibrous or fibro-cellular type, depending on their size; they exhibit a cuticle, a cortex, and a medulla. There is a gradual transition between the soft hairs and ridged spines at the sides of the animal.

The spines are gigantic, somewhat modified hairs, consisting of a cuticle, a cortex, and a medulla.

The cuticle is a single layer of large imbricated scales.

The cortex is fibrous in appearance, contains pigment at intervals, and is strengthened internally by twenty-two to twenty-four longitudinal ridges that project inwards for some distance into the medulla.

The medulla is of large size, thickest in the middle of the shaft, tapering towards the tip and neck of the spine; it is divided into narrow lenticular chambers by transverse imperforate septa, each of which splits horizontally at the margin into several leaflets, which in their turn again split horizontally into still smaller leaflets; all the leaflets are firmly attached to the sides of the inward projecting cortical ridges, thereby firmly binding them together and helping them to withstand a vertical strain, the septa themselves preventing undue distortion of the spine from a transversely applied strain. Morphologically the spines are true hairs.

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10. *On the Industry and Intelligence of Insects in relation to Flowers.* *By* Rev. Alex. S. Wilson.

TUESDAY, AUGUST 9.

The following Papers were read:—

Department of Botany.

1. *Tubercles on the Thallus of some Florideæ.* *By* Professor Schmitz, *of Greifswald.*

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2. *On a Comparison of the Marine Floras of the warm Atlantic and the Indian Ocean.* By George Murray, *F.R.S.E., F.L.S.*

The following tables show in the first six columns the total number of genera and species in the areas chosen for comparison, together with the intervening Cape region, while the remaining eight columns are devoted to the analysis of these totals.

—	Warm Atlantic		Cape of Good Hope		Indian Ocean		Algæ common to							
							Warm Atlantic and Cape		Indian Ocean and Cape		Warm Atlantic and Indian Ocean		Warm Atlantic, Indian Ocean, and Cape	
	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.
Florideæ:														
Ceramieæ	6	47	6	12	7	21	4	2	6	3	5	10	4	2
Cryptonemiaceæ	9	30	4	4	5	16	1	1	1	1	5	4	1	1
Gigartineæ	10	28	5	15	6	18	5	3	5	2	6	6	5	1
Spyrideæ	1	6	1	1	1	3	1	0	1	0	1	3	1	0
Areschougieæ	1	1	0	0	0	0	0	0	0	0	2	3	0	0
Champieæ	2	7	2	3	2	7	2	0	2	1	3	2	2	0
Rhodymeniaceæ	6	22	5	11	5	10	2	2	3	2	1	0	2	1
Squamarieæ	2	3	0	0	1	2	0	0	0	0	2	1	0	0
Porphyraceæ	2	6	2	6	2	6	2	1	2	1	2	1	2	0
Sphærococcoideæ	4	63	3	4	6	22	1	1	1	1	2	7	1	1
Delesserieæ	3	8	4	9	2	3	2	1	1	0	2	1	1	0
Helminthocladiaceæ	6	41	1	2	6	24	1	1	1	0	4	10	1	0
Chætangieæ	2	2	1	3	2	2	1	1	2	1	1	1	1	1
Gelideæ	5	17	3	8	2	12	3	5	2	4	2	3	2	2
Hypneaceæ	2	22	1	2	2	12	1	2	1	2	1	9	1	2
Solieriеæ	4	12	1	1	3	6	1	1	1	1	2	2	1	1
Wrangelieæ	1	2	0	0	1	1	0	0	0	0	0	0	0	0
Chondrieæ	2	25	2	7	2	16	1	4	1	3	2	8	1	3
Lomentarieæ	1	1	0	0	1	2	0	0	0	0	1	0	0	0
Rhodomeleæ	14	96	10	27	18	48	8	5	7	3	12	12	7	1
Corallineæ	7	43	8	28	6	24	6	11	6	5	5	12	5	3
Total	90	482	59	143	80	255	42	41	43	30	61	95	38	19
Phæophyceæ:														
Fucaceæ	4	38	8	19	4	59	3	5	2	5	3	10	2	3
Dictyotaceæ	7	45	4	19	7	23	4	9	4	5	4	9	4	5
Ectocarpaceæ	1	15	3	5	2	12	1	2	1	1	1	2	1	1
Sphacelariaceæ	2	4	2	4	1	5	2	2	1	2	1	1	1	1
Chordariaceæ	6	9	1	2	5	7	0	0	1	1	3	2	0	0
Punctariaceæ	1	1	0	0	1	1	0	0	0	0	0	0	0	0
Arthrocladiaceæ	1	3	0	0	1	2	0	0	0	0	1	2	0	0
Sporochnaceæ	3	9	2	5	2	7	1	1	1	1	2	3	1	1
Laminareæ	0	0	5	6	0	0	0	0	0	0	0	0	0	0
Ralfsiaceæ	1	1	1	1	1	1	1	0	1	0	1	0	1	0
Total	26	125	26	61	24	117	12	19	11	15	16	29	10	11
Chlorophyceæ:														
Siphoneæ	23	99	6	12	16	72	5	3	5	4	16	29	6	3
Conferveæ	4	80	3	15	8	39	2	4	3	3	4	13	2	1
Ulveæ	5	20	3	9	2	10	2	3	2	2	2	4	2	2
Total	32	199	12	36	26	121	9	10	10	9	22	46	10	6
Protophyceæ, total	14	51	2	2	9	21	0	0	0	0	5	4	0	0
Aggregate	162	859	99	242	139	514	63	70	64	54	105	174	58	36

3. *On the Structure of the Stem of a Typical Sigillaria.* *By* W. Carruthers, *F.R.S.*

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4. Calamostachys Binneyana (*Schimp.*). *By* Thomas Hick, *B.A., B.Sc.*

The object of this paper is to revise our knowledge of the structure and affinities of *Calamostachys Binneyana* in the light of a series of preparations which have not hitherto been described or published.

The spike consisting of an axis surrounded by alternating whorls of bracts and sporangiophores, the structure of each of these is examined in detail and compared with the descriptions already published by Carruthers, Binney, and Williamson.

The central part of the axis, hitherto described as vascular, the author finds to be cellular, and to form a true pith which is circular or triangular in the transverse section.

Round the pith are, usually, three primary vascular bundles, which are reduced to the condition of those met with in the stems of *Equisetum* and the youngest branches of *Calamites, i.e.*, to as many carinal canals, with annular or spiral vessels adhering to the wall. When secondary thickening occurs it commences at these carinal canals, and usually three wedge-shaped masses of secondary xylem are first formed; subsequently these may be united to form a complete zone.

The cortical tissues of the axis, the 'nodal discs,' the bracts, and the sporangiophores are described with additional detail, and special attention is called to a layer of large cells, often with black contents, which is found near the margin of the 'nodal discs,' and forms the lower or outer half of the bracts.

A few additional details are also given of the structure of the sporangia, the most important of which is the presence of a small mass of non-sporogenous tissue at the proximal end, where the sporangia are contracted into the peduncles.

As to the affinities of the spike, the structure described is held to demonstrate that it belongs to some carboniferous plant whose affinities are more or less close with the existing genus *Equisetum*. Such a plant we have in *Calamites*, to which the spike was referred by Carruthers in 1867. Against this determination Williamson set the vascular structure, as it was then interpreted, of the central part of the axis, and, relying on this, referred *Calamostachys Binneyana* to the Lycopodiaceæ. The proof now adduced that the centre of the axis is cellular removes the objection raised by Williamson and brings us back to *Calamites*. The discovery of carinal canals at the periphery of the pith, as representatives of the primary vascular bundles, gives all that is needed to confirm this view, and leaves little or no doubt that *Calamostachys Binneyana* is the fruit of some form of *Calamites*.

Beyond this it is difficult to go. There are, however, two facts that suggest that the spike is probably the fruit of a *Calamites* of the *Arthropitys* type. These are (i.) that *Arthropitys* is the only form with structure found in Yorkshire and Lancashire where *Calamostachys Binneyana* is met with; and (ii.) that in the stems and leaves of *Arthropitys* we have a layer of large cells, with frequent black contents, such as are found in the nodal discs and bracts of the spike.

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5. *Notes on Specimens of Myeloxylon (Brong.) from the Millstone Grit and Coal-measures.* *By* A. C. Seward, *M.A., F.G.S.*

A number of specimens of Myeloxylon examined by the author lend support to the views of Schenk and others, that the anatomical structure of this fossil plant agrees more closely with that of cycadean petioles rather than with the petioles of ferns. Whilst recognising a number of characters which suggest a cycadean affinity, there are noted one or two points which render it probable that Myeloxylon may eventually find its true position intermediate between ferns and

cycads. The specimen which supplies the most important evidence in the question as to relationship with living plants is one from the collection of the late Mr. Binney. In many of the vascular bundles of this Oldham example the phloem is well preserved, and a longitudinal section clearly demonstrates the position of the protoxylem. In examples previously described and figured the position of the protoxylem has been inferred from the appearance, in transverse sections, of the xylem tracheids; in the longitudinal section of the Oldham Myeloxylon the small xylem tracheids next to the phloem are seen to be spirally thickened, and are without doubt protoxylem.

Another example of Myeloxylon described was found in a limestone band of Millstone Grit age: this furnishes facts of some interest in connection with the question of botanical affinity, and as regards fossilisation. Hitherto English specimens of Myeloxylon have only been found in the Coal-measures.

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6. *Observations on the Structure of* Cystopus candidus.

By Harold W. T. Wager.

In this paper a short account is given of the structure of the vegetative and reproductive organs of *Cystopus candidus*, a fungus parasitic on cruciferous plants, and especially abundant on the common shepherd's-purse—*Capsella bursa-pastoris*—on which it forms white shining patches, often of considerable extent on the stem, leaves, and fruits.

The mycelium consists of non-septate hyphæ which ramify in all directions between the cells of the host plant, and often produce extensive hypertrophy of the organ attacked. Here and there small spherical haustoria are developed on the hyphæ, and these penetrate directly into the cell cavities.

Both hyphæ and haustoria contain a granular protoplasm, in which numerous nuclei can be seen. The structure of these nuclei can be made out by careful staining and examination under a sufficiently high power, as was shown by Fisch, with whose observations mine in the main agree. Each nucleus is vesicular, and contains a large nucleolus which stains deeply and is surrounded by a less deeply stained substance, in which some indications of a granular or thread-like structure may at times be observed.

The reproductive organs are of two kinds, asexual and sexual. The asexual organs are formed just beneath the epidermis of the host plant: they are club-shaped branches of the mycelium, from which zoosporangia are cut off by constriction and formation of a double cell wall at the apex. These branches contain granular protoplasm derived from the mycelium, and numerous vacuoles. A few nuclei are found scattered in the protoplasm, the number being variable, from five to twelve. The structure of the nucleus is similar to that in the mycelium, but is more easily made evident.

In the formation of a sporangium a part of the protoplasm accumulates at the apex, together with a few nuclei, four or five, or perhaps more; this is then separated from the club-shaped branch by constriction of the cell membrane. A double cell wall is then formed which completely cuts off the sporangium from the branch on which it is formed. The sporangium is thus, from the beginning, a multinucleated cell. Each nucleus at a later stage becomes the nucleus of a zoospore without undergoing further division.

The nuclei found in the club-shaped branches are probably derived directly from the mycelium, no division stages having been observed in the sporangiophore itself. It is possible, however, that owing to the smallness of the nuclei the division stages are masked.

The sexual organs, antheridia and oogonia, also contain numerous nuclei. According to Fisch the oogonium contains from ten to twenty nuclei, the antheridium three or four. I find more than this in many cases. In the formation of the oosphere the protoplasm separates into periplasm and gonoplasm, a cell wall appears round the gonoplasm; a large number of nuclei remain in the periplasm, but the gonoplasm does not appear to possess nuclei at this stage; at a later stage,

however, during the formation of the exospore a number of nuclei make their appearance in the oospore around a central oil-globule. These observations do not agree with those of Fisch. According to this observer all the nuclei of the oogonium fuse together to form the nucleus of the oosphere. According to Dangeard the central nucleus of Fisch is nothing more than an oil-globule, and, so far as my observations go, I agree with him. Soon after the separation of the oosphere a quantity of oil begins to accumulate in or near the centre. This is stained deeply by hæmatoxylin or picro-nigrosin, and might be easily mistaken for a nucleus. Its oily nature may be determined, according to Dangeard, by soaking the sections for some time in chloroform, when it disappears and a vacuole is left. The oil-globule gradually increases in size until the exosporium is fully formed. It then takes up about one-third of the diameter of the cavity of the oospore.

The disappearance of the nuclei of the oosphere during the earlier stages of its development is probably only apparent, some change taking place, of the nature of which we are not yet cognisant. It is probable that these nuclei are included in the oosphere at the time of its separation from the gonoplasm.

The problem of fertilisation is an important one, but is difficult to settle. At an early stage the antheridium contains numerous nuclei which pass over at a later stage into the fertilising tube of the antheridium, but whether they pass into the oospore is a question which I have not been able to settle.

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7. *On the Affinity of Nuclein for Iron and other Substances.* By Professor G. Gilson, *of Louvain.*

An iron-holding nuclein was discovered some years ago by Bunge[1] in the yolk of the hen's egg, and another by Zaleski[2] in the liver cells of various animals. Grounded on these two observations, as well as on some personal researches, Macallum, of Toronto, was led to the generalisation that the nuclein of every cell contains iron as a necessary constituent of itself. I know also that R. Schneider, in 1888, presented to the Physiological Society of Berlin microscopical preparations showing the reaction of iron in the nucleus; but I have not been able to find out where he published an account of his work.

Macallum, like Schneider,[3] tried to detect iron in the nucleus itself by microchemical means. He succeeded in that by keeping cells under the action of ammonium sulphide, in a warm oven, a rather long time—two or three weeks. Recently, however, he declared he has arrived at the same results by a much easier process;[4] but, as far as I know, he has not, up to this time, published his new method. The biological importance of Macallum's conclusion is too obvious to need any further explanation. But on the other hand, as long as there remains the slightest doubt about the fact itself, all kinds of theoretical considerations on the subject would be of no use to positive science. I took upon myself to verify Macallum's observations, and I found very soon that the question is by far more difficult than it might appear.

I also succeeded in detecting iron in the nucleinic elements or chromatosomes of the nucleus, not only by the action of ammonium sulphide alone, but by various other means.

Generally speaking, an intact nucleus gives no reaction with the usual reagents of iron compounds. But I remarked, on the contrary, that when nuclein has been recently submitted to the action of *various chemical agents*, it very clearly gives evidence of the presence of the metal. Amongst the numerous substances I

[1] Bunge, 'Ueber die Assimilation des Eisens,' *Zeitsch. f. Phys. Chemie*, vol. ix. p. 49.

[2] Zaleski, 'Studien über die Leber,' *ibid.*, vol. x. p. 453.

[3] Macallum does not quote Schneider's observations, and seems not to be aware of their existence.

[4] Macallum, *Proc. Roy. Soc.*, April 30, 1891.

tried, sulphuric acid and sulphurous anhydride gave the best results, though many other agents, especially saline solutions, produce the same effect.

When nuclei, previously steeped for a certain time in these liquids, are treated with ammonium sulphide their chromatic elements take a greenish-black colour, while the action of an acidulated solution of potassium ferricyanide gives them an intense blue colour, caused by the formation of Turnbull's blue.

These reactions are strictly limited to the chromatic filaments or chromatosomes of the nucleus, the protoplasm remaining absolutely colourless. In presence of such a perspicuous reaction, there cannot remain the slightest doubt about the presence of iron in the nucleinic elements actually under observation.

But a question now arises: Is Macallum right when he contends that 'the chromatin of every cell, animal or vegetable, is an iron compound'?—that is to say, a regular chemical combination with fixed proportions.

I have no peremptory objection to oppose to Macallum's conclusion. But, though his experiments seem to have been carefully carried out, I must confess I am not entirely satisfied with the accuracy of his generalisation, and cannot help thinking that the union of nuclein with iron might be a rather accidental combination taking place after death only, and similar to that which it effects with many other substances, especially colouring matters.

This suggestion is not a mere supposition; it proceeds from some observations I have made lately.

I was able to ascertain that dead nuclein has a very strong affinity for iron compounds. The nuclei of freshly extracted cells, when steeped in a solution of sulphate of iron, $FeSO_4$, even as weak as 1 for 2,000 parts of water, take with ammonium sulphide or potassium ferricyanide a much more intense colouration than they did before, when simply treated with sulphuric acid. A consequence of that observation on dead nuclein is, that it is extremely difficult to ascertain whether living nuclein really contains iron, or whether it only absorbs it, after it has been killed, out of the blood or other surrounding liquids, or even out of the reagents themselves if they are not absolutely free from iron. Biologists ought therefore to test their reagents very carefully before using them, and also to take great care to avoid the contact of the slightest trace of organic or inorganic iron with the cells. And that is not an easy task at all, for everyone knows that this metal spoils everything, and is everywhere throughout nature.

For my part, though my reagents were as pure as possible, I am not certain at all, as far as the present, that the iron made visible in my preparations really belonged to the living nuclein, and had not been absorbed after death only. Macallum did not experimentally ascertain this affinity of nuclein for iron compounds. I know, however, that he used to treat his objects with an acidulated alcoholic mixture, called Bunge's fluid, a liquid which is supposed to take out, after ten hours of action, all the organic and inorganic iron, excepting that combined with nuclein. But I have observed that Bunge's liquid does not take away the iron artificially combined with dead nuclein even after six days.

I observed also that various iron compounds are attracted by nuclein, and that its affinity is stronger for the ferrosum radical than for the ferricum. But iron is not the only metal which nuclein can absorb and retain. I succeeded in fixing in it manganese, nickel, and even copper, which all gave in the nucleus only their usual reactions. Nickel is almost as strongly attracted as iron itself is. Molybdenum also is retained by nuclein, and this last observation induces me to be cautious about another method of micro-chemical technic recently published. Dr. Lilienfeld, just a month ago, announced he had discovered a method of detecting phosphorus in the nucleus, with the aid of ammonium molybdate and pyrogallol. I suspect that the yellow-brown colouration he regards as characteristic of the phosphorus is caused by the accumulation of ammonium molybdate in the nuclein; the brownish colouration that ammonium molybdate itself gives with pyrogallol is darker in the nucleus, not because nuclein contains phosphorus, but because it retains more of the ammonium molybdate than the protoplasm does.

I may add also that other substances found in the cell have a similar attraction for iron. Macallum pointed out that amyloid substances contain iron, and I

have observed that the silk of certain insects (chironomus, for instance) seems to possess a stronger affinity for this metal than nuclein itself.

To sum up briefly the present state of the question, it is now certain that *dead* nuclein, as well as other substances found in the cell, have a very strong affinity for various compounds of iron and of other metals, or even negative chemical bodies. Thus the difficult question arises, whether the presence of iron in the nucleinic element *during life* is constant and normal, and whether this metal is necessary for the chemical activity of the nucleus.

I hope these remarks will induce other biologists to undertake similar researches on a question that seems to require more than a single man's activity; and that is the reason why I resolved to publish my results in their present incomplete form.

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8. *A Method of Staining Chromatin by Chemical Means.* *By* Professor G. Gilson, *of Louvain.*

The fact that metallic compounds are easily fixed in nuclein suggested to me a peculiar method of staining nuclei that, perhaps, might be of some use for special histological and cytological researches. It consists either in keeping cells, previously hardened, in the metallic solution during a certain time, or in adding this latter directly to the usual fixing liquids. Then, after the solution has been thoroughly washed out, the objects are put into ammonium sulphide or potassium ferricyanide, or into both, and washed again.

I succeeded by this method in staining the chromatic elements of many animal and vegetable cells, after the action of picro-sulphuric acid, Perenyi's fluid, corrosive sublimate, especially the acid solution used in my laboratory, and others. But I did not succeed up to the present, after using Flemming's fluid or other chromic liquids.

The colouration is always characteristic, provided the object has been sufficiently washed before the reagent is applied.

I am still studying the best method to get a good dark colouration. Satisfactory results, however, have been obtained with the following solution, as well for fixing and hardening the cell as for staining the nuclei:—

	c.c.
Iron sulphate, 10 per cent. aq.	10
Nitrate of nickel, 50 per cent. aq.	10
Alcohol, 90 per cent., or, better, aldehyde saturated with sulphurous anhydride	10
Sulphuric acid	2
Alcohol, 90 per cent.	40
	72

After some hours' steeping in this fluid, objects are washed with weak alcohol, then with water, and put into ammonium sulphide for a few minutes. After another washing with alcohol and with water they are steeped for about half an hour in a weak solution of potassic ferricyanide acidulated with hydrochloric acid and washed again.

Each of the substances composing the solution, except alcohol, has the effect of making nuclei colourable with ammonium sulphide or with potassium ferricyanide; but I noticed that better results are obtained when they are mixed together in the above-mentioned proportions.

The action of potassium ferricyanide is much quicker and more intense when it succeeds that of ammonium sulphide. This latter does not harm in the slightest way the cells previously treated with the mixed solution or with the usual fixing liquids, though it seems better, at all events, not to use it too concentrated.

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9. *A proposed Reform in Botanical Nomenclature.* *By* James Britten.

10. *Conditions affecting Plant Life in a Town Atmosphere.* *By* G. H. Bailey, *D.Sc., Ph.D.*

Although it is well known that plants in towns exist under very unfavourable conditions, there is very little precise information as to the nature of these conditions. A series of observations extending over more than a year, and carried out by the Town Gardening Committee of the Manchester Field Naturalists, in conjunction with the Royal Horticultural Society, have supplied many important details, a summary of which is given below.

1. A comparative measure of the amount of light received each day at stations in different parts of Manchester and district and in other localities shows that, whilst the record for the suburbs of a large town falls below that of a country district, there is a still greater falling off to the extent of 50 per cent., or even more, within the town area. For the same period of the year the measure for bright sunshine is ten to twenty times that for dull weather, and as much as 300 times that during dense fog. As to the effect of the season, an hour's sunshine at midday in June gives five times the record of that for December.

Moreover, comparative measures for sunshine taken simultaneously in Switzerland, Torquay, and the suburbs of Manchester were in the proportion 20 : 11 : 3.

2. The amount of sulphurous acid in town air in heavy weather is ten to twenty times that in bright clear weather, and in fog the proportion is still greater.

3. Freshly fallen rain collected in Manchester showed as much as seventy parts per million of sulphuric acid.

Snow is usually more free from sulphuric acid than rain, whilst rime, which has formed on the leaves during frost, is by far the most impure form of moisture which comes in contact with plants, and samples have been collected containing nearly 400 parts per million of sulphuric acid. Estimations have also been made of the amount of organic matter and soot deposited on the leaves of plants, and the nature of the deposit has been examined.

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11. *Some Albucas and their Hybrids.* *By* John H. Wilson, *D.Sc., F.R.S.E.*

The African liliaceous genus, Albuca, is easily recognised by the cucullate and connivent inner segments of the perianth, which commonly conceal the essential organs as in a capsule. The writer confined his remarks to the following species:—*A. corymbosa*, *A. fastigiata*, *A. caudata*, *A. juncifolia*, *A. trichophylla*, *A. major* (?), and an unidentified species.

During the past six years a number of hybrids have been raised by the writer.

Using the initial letter as an abbreviation of the specific name, and placing the seed-bearing parent before the sign of hybridity, the following is the series involving *A. fastigiata* and *A. corymbosa*:—$f \times c$, $(f \times c) \times c$, $(f \times c \times c) \times c$, $(f \times c) \times (f \times c \times c)$, $(f \times c) \times f$, $c \times (f \times c)$, $c \times (f \times c \times c)$.

The following involve *A. trichophylla*, *A. juncifolia*, and *A. major*:—$t \times c$, $t \times f$, $t \times (f \times c)$, $f \times c) \times j$, $f \times j$, $(f \times c) \times m$.

During the present summer capsules of a series of hybrids having *A. caudata* (*ca*) as one of the parents has been secured, viz.:—$ca \times c$, $ca \times (f \times c)$, $f \times ca$, $(f \times c) \times ca$.

Two capsules were also borne by the unidentified species, resulting in the one case from double pollination by $t \times (f \times c)$, and m; and in the other by c, and $t \times (f \times c)$. It will be instructive to see, by study of the hybrids furnished by these experiments, which pollen of the three kinds applied has been effective.

A brief description of the prominent features of the hybrids of previous years was given, reference being especially made to the bulbs which, no less than the flowers and foliage, afford many points of interest. The characters of certain of them have already been discussed ('Botanisch Jaarboek,' vol. iii. 1891, p. 233).

Hybrids between species having in the one parent erect, and in the other cernuous flowers, are $t \times c$, $t \times (f \times c)$, and $(f \times c) \times j$. The characters of both parents are fairly equally blended in the first two. The flowers during the day

rise to a position more or less nearly horizontal. The outer anthers are poorly developed, and bear a very little pollen. A single specimen of the hybrid $(f \times c) \times j$ has just flowered, and shows some notable features, but it is not as yet far enough advanced to admit of full description.

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12. *The Embryo-sac of Angiosperms is a Sporocyte and not a Macrospore.* By Gustav Mann, *M.B., C.M.*

The development of the ovule and its embryo-sac has been studied in *Myosurus minimus*, L. Three stages may be distinguished:—

1. An early stage, during which one physiological and several non-physiological archespores and one physiological and two or three non-physiological embryo-sac-cells are formed.

2. An intermediary period, ending with the formation of eight sexual nuclei within the sac.

3. A final stage, during which the ovum matures and the primary endosperm-cell is formed by the conjugation of two sexual primordial cells.

A. *Early Stage.*—There are several archespores, but only one undergoes further development, and this, the physiological one, divides into two cells, one of which lies next the plerome elements of the ovule. This one attains a larger size, and precedes in redivision its sister cell, which abuts on the dermatogen.

Four cells are thus derived from the physiological archespore, and of these that one lying next the plerome develops into the physiological embryo-sac; the three remaining cells must be regarded as non-physiological embryo-sacs. In all the cells derived from the functional archespore, gelatinisation of the cell-walls takes place—a phenomenon quite analogous to that occurring in other sporocytes, *e.g.*, pollen-mother-cells, and in all probability analogous to what occurs in animal ova generally, the zona pellucida being the wall of a sporocyte, the ovum proper equalling physiologically a female cell, the polar bodies being non-physiological female cells.

The author's view has been confirmed by (1) Guignard, who discovered that in the embryo-sac and pollen-mother cell, at the time of their formation, the number of chromatin segments becomes reduced by half; (2) by Dodel and Overton, who discovered, quite independently of each other, that the synergidæ are non-physiological ova, as proved by the fact that they may become fertilised and develop into embryos.

B. *Intermediary Period.*—The functional embryo-sac cell shows no gelatinisation in that cell-wall which is in contact with the plerome elements to allow a ready transit of nutritive material through it.

The embryo-sac cell enlarges, one or more vacuoles are formed, and the nucleus divides. The protoplasm does not divide immediately, but does so later on, in about 50 per cent. of cases, by the formation of one or two membranes separating the apical half of the sac from the basal half.

The two nuclei in the sac divide and redivide, thus giving rise to eight nuclei: namely, the ovum, two synergidæ, two primordial cells, and three antipodes. The basal half of the sac, being supplied more abundantly with nourishment, precedes the apical half in division; its monasters are larger, &c.

C. *Final Stage.*—As the sac enlarges the nucellar cells and the non-functional embryo-sacs perish; albuminoid compounds, set free by their death, enter the apical end of the physiological or functional embryo-sac, the basal end and the ovum being supplied with food derived from the plerome elements. This is the reason why the nuclei of the synergidæ are placed next the dermatogen; why the nucleus of the ovum is placed next the cavity of the sac; why the vacuoles occupy respectively the reverse position. The synergidæ are, normally, non-functional, because want of food leads to their degeneration before the flower is ready for conception.

The two primordial cells giving rise to the primary endosperm-nucleus (Strasburger's secondary nucleus) are sexual cells; and the resulting zygote is a true

embryo, which, however, is destined to be consumed by the stronger embryo which is the offspring of the ovum and the extraneous sexual cell derived from the pollen-grain.

The three antipodes usually do not act as sexual cells, but they may perhaps undergo a conjugation similar to that occurring between the two primordial cells (*Scilla nutans*).

Criticism of the current assumption that the embryo-sac is a macrospore.

Summary of facts in favour of the view, first advanced by the author, that the embryo-sac is a sporocyte.

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13. *On the Disappearance of Native Plants from their Local Habitats.* *By* Professor W. Hillhouse, *M.A., F.L.S.*

The following list was compiled from various correspondents in continuation of the Reports of the Committee formed for the purpose in 1886.

The list deals with the West of Scotland, and the materials were collected mainly by a special sub-committee of the Natural History Society of Glasgow. The numbering is that of the 'London Catalogue of British Plants,' edition 8.

5. *Thalictrum flavum*, L. Formerly on the bank of the R. Clyde at Clyde Iron Works, Lanarkshire; now extinct, from unknown cause (D. A. B.).

13. *Ranunculus fluitans*, Lam. In a small stream between Clydebank and Dalmuir, Dumbartonshire; extinct, through stream being used for sewage (L. W.).

23. *R. sceleratus*, L. Marshy ground on side of R. Clyde between Clydebank and Dalmuir, Dumbartonshire; extinct; marsh reclaimed (L. W.).

39. *Trollius europæus*, L. Formerly, but scarce, on banks of Gourock Burn, West Kilbride, Ayrshire; extinct (D. A. B.).

59. *Glaucium flavum*, Crantz. Seashore between Dunoon and Toward, Argyllshire; extinct, probably all gathered by collectors and summer residents (T. K.).

89. *Arabis Turrita*, L. Old quarry in wood near Partick, Lanarkshire extinct since about 1880 (T. K.).

107. *Cochlearia officinalis*, L. As No. 23 (L. W.).

138. *Senebiera Coronopus*, Poir. Waste ground on seashore at Seamill, Ayrshire; extinct, washed away during a high tide, January 1884 (D. A. B.).

249c. *Lepigonum neglectum*, Kindb. As Nos. 23 and 107 (L. W.).

277. *Malva moschata*, L. Reported formerly to grow below Innellan, Argyllshire; now apparently extinct, from an unknown cause (T. K.).

352. *Trifolium striatum*, L. Sandy fields at Seamill, Ayrshire; extinct in several places where formerly abundant, on ground now built over (D. A. B.).

506. *Rosa spinosissima*, L. Among coarse grass on seashore, Seamill, Ayrshire; extinct in several spots where formerly abundant, washed away during a high tide, January 1882 (D. A. B.).

589. *Peplis Portula*, L. Quarry-hole in field behind Tarbert Hill, West Kilbride, Ayrshire; extinct; site filled up by farmer (D. A. B.).

672. *Daucus Carota*, L. Waste ground, Seamill, Ayrshire; extinct; ground now built over (D. A. B.).

800. *Carduus crispus*, L. The same (D. A. B.).

917. *Andromeda Polyfolia*, L. Stewarton Moss, Ayrshire; extinct; within the last thirty years, from unknown cause (D. L.).

— [*Ledum palustre*, L. Lecropt Moss, West Perth; formerly in considerable quantity, but almost extirpated by botanical class from Edinburgh University, who were guided to the spot by a local botanist (J. Sh.).]

941. *Primula vulgaris*, Huds. Island of Cumbrae, Buteshire; rapidly diminishing, being carried off in basket loads by lady visitors (D. R.).

993. *Mertensia maritima*, Don. Seashore between Dunoon and Toward, Argyllshire; extinct on all parts of the shore till far past Toward, being probably all gathered by collectors and summer visitors (T. K.).

1006. *Echium vulgare*, L. On sandy soil, Bog Farm, Stevenston, Ayrshire: extinct, being smothered by drifting sand (J. S.).

1009. *Calystegia Soldanella*, R. Br. Fintry Bay, Cumbrae, Buteshire; extinct, mainly, it is believed, through ravages of botanical students from Glasgow (J. K.).

1131. *Scutellaria minor*, L. Rosebank, Cambuslang, Lanarkshire; extinct, through railway construction (D. A. B.).

1270. *Myrica Gale*, L. Biglus Moor, West Kilbride, Ayrshire; extinct, through draining of bog (D. A. B.).

1329. *Neottia Nidus-avis*, Rich. Wood near Kilwinning, Ayrshire; extinct, rooted out by school children who were receiving instruction in botany (J. S.).

1338. *Cephalanthera ensifolia*, Rich. Island of Arran, Buteshire, and Cunninghead, Ayrshire; extinct, all the plants being dug up for removal to gardens (D. L.).

1380. *Narcissus Pseudo-narcissus*, L. On banks of Gourock Burn, West Kilbride, Ayrshire; formerly abundant, but now greatly reduced in number, being carried off to gardens (D. A. B.).

1385. *Galanthus nivalis*, L. Crosbie Glen, West Kilbride, Ayrshire; formerly removed in large quantities to gardens, but removal now prohibited by proprietor (D. A. B.).

1470. *Alisma Plantago*, L.
1477. *Triglochin maritimum*, L. } As No. 23 (L. W.).

1479. *Potamogeton natans*, L.
1496. *P. crispus*, L.
1502. *P. pusillus*, L. } Paisley Canal, Renfrewshire; almost extinct, as the canal is drained and a railway made along greater part of its course.

1534. *Scirpus Tabernæmontani*, Gmel. As No. 23 (L. W.).

1538. *Scirpus maritimus*, L. The same (L. W.).

1541. *Scirpus rufus*, Wahlb. Bank of Clyde, between Old Kilpatrick and Bowling, Dumbartonshire; habitat slowly disappearing, being washed away by the tide (L. W.).

1560. *Carex disticha*, Huds. In a ditch between Dalmuir Burn and Old Kilpatrick, Dumbartonshire; ground reclaimed, ditch drying up, and plants in it disappearing (L. W.).

1561. *Carex arenaria*, L. Seashore, Seamill, &c., Ayrshire; since 1882, owing to a series of remarkably high tides, the sandbanks, formerly protected by the rhizomes and roots of this plant, have been considerably reduced in extent (D. A. B.).

1582. *Carex acuta*, L. As No. 23 (L. W.).

1667. *Ammophila* (*Psamma*) *arundinacea*, Host. *See* No. 1561, the remarks in which apply, even more strongly, to this plant (D. A. B.).

1687. *Phragmites communis*, Trsn. As No. 23 (L. W.).

1766. *Cryptogramme crispa*, R. Br. Western Islands, &c.; large numbers of fern roots, exposed on barrows, are frequently offered for sale in the streets of Glasgow, and it is believed that the main supply is derived from the Western Islands (Arran, Jura, &c.), and the Argyllshire Hills (D. A. B.).

1770. *Asplenium Adiantum-nigrum*, L. The same (D. A. B.).

1771. *A. marinum*, L. The same (D. A. B.). Also Chapelton Wood, West Kilbride, Ayrshire; nearly extirpated by collectors (D. A. B.).

1772. *A. viride*, Huds. *See* 1766 (D. A. B.).

1773. *A. Trichomanes*, L. The same (D. A. B.).

1781. *Ceterach officinarum*, Willd. On a wall near Paisley, Renfrewshire; formerly plentiful, but now almost extinct, taken, it is believed, by a fern-dealer (T. K.).

1782. *Scolopendrium vulgare*, Symons. Portincross Woods, Ayrshire; formerly carried off in large quantities, but removal now forbidden by proprietor (D. A. B.).—Hindog Glen, Dalry, Ayrshire; abundant thirty years ago; but since extirpated (J. S.).—Island of Cumbrae, Buteshire; about fifty years ago this fern was growing abundantly on the island, now it is difficult to find a single plant. It has been said that the ferns have been taken by nurserymen for their own interests. In summer, however, the lady visitors were seldom seen leaving the island without a basket of ferns—a practice carried on year after year, till now,

when the ferns are nearly exhausted, the gathering mania is passing from ferns to primroses (*see* remarks on No. 941. D. R.).—The remarks on No. 1766 are applicable also to this species as a plant of the Western Islands, &c. (D. A. B.).

1806. *Osmunda regalis*, E. Hunterston, Ayrshire; formerly luxuriant on the cliffs and low ground facing the sea, but now extinct, the plants being carried away (D. L.).—Portincross, Ayrshire; a few plants formerly grew here, but were all dug up and carried away (D. A. B.).—Shewalton Moss, Dundonald, Ayrshire; extinct, the moss being reclaimed (J. S.).—Island of Cumbrae, Buteshire; formerly plentiful in places; this fern has now almost entirely disappeared, being carried away with 1782 and others (D. R.).—Island of Arran, Buteshire; up till 1860 abundant in many places, but now extinct, or nearly so, having been carried away by cartload and boatload (D. L.). Roots are sometimes still offered for sale to visitors in the island (D. A. B.).—Achacha District, Benderloch, Argyllshire; formerly plentiful, but now none has been seen for twelve or fourteen years, the roots having been continually sought after and removed by collectors (W. A. S.).—Loch Fyne District, Argyllshire; becoming extremely rare through ruthless collections for sale (W. A. S.).—Western Islands, &c.; *see* remarks on No. 1766, very applicable to this species (D. A. B.).

1822. *Lycopodium Selago*, L. Mons, near West Kilbride, Ayrshire; much less common than formerly, probably owing to drainage (D. A. B.).—Western Islands, &c.; occasionally exposed for sale in the streets of Glasgow. As No. 1766, &c. (D. A. B.).

Department of Zoology.

1. *Présentation de Planches inédites de Zoologie concernant les Recherches du Yacht 'l'Hirondelle.'* Par Baron Jules de Guerne.

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2. *Crustacés Copépodes des Eaux sursaturées de Sel de la France et des Canaries.* Par Baron Jules de Guerne.

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3. *Observations on the Development of the Posterior Cranial and Anterior Spinal Nerves in Mammals.* By Arthur Robinson, *M.D., Senior Demonstrator of Anatomy at the Owens College, Manchester.*

1. In cat and rabbit embryos of eleven proto-vertebral somites, and in mouse and rat embryos of a similar stage of development, a continuous cord of nerve-cells extends backwards from just within the posterior part of the auditory depression along the dorso-lateral angle of the medulla and spinal cord. At this period the cord of cells is connected with the dorsal extremity of the neural tube by a series of cellular strands, which are so numerous and so closely opposed that they almost form a continuous lamina, which is only one cell thick.

2. During the period of formation of the secondary optic cup this cellular cord (*a*) loses its connection with the dorsal extremity of the neural tube; (*b*) becomes thickened in the region between the auditory vesicle and the first somite; (*c*) remains relatively small from the first to the fourth somite; (*d*) beyond the fourth somite it gives origin to a series of swellings, the spinal ganglia.

3. At a later period, in cat embryos of 9 mm., in mice of from $2\frac{1}{2}$–5 mm., and in rat embryos of a similar stage of development, the cord of cells in the region of the first four somites is enlarged in three places. One enlargement is situated in relation with the fourth somite, which is in the cervical region; the other two are in relation with the second and third somites, which belong to the occipital region. The cellular cord is also enlarged in the region of the first somite, but this enlargement is continuous with the enlargement in the pre-somitic region, and cannot be distinctly separated from it.

4. (*a*) The ganglionic enlargement in the pre-somitic region becomes converted into the root ganglia of the glosso-pharyngeal and vagus nerves.

(*b*) The ganglionic enlargement in relation with the fourth somite becomes the first cervical ganglion.

(*c*) In the rat and the mouse the ganglionic enlargements in relation with the second and third somites become connected with the spinal accessory nerve, but in the cat the enlargement in relation with the third somite becomes united with the most posterior root of the hypo-glossal nerve.

5. After the separation of the cellular cord from the dorsum of the neural tube a series of nerve roots are developed, and by means of these the cellular cord and its ganglionic swellings become secondarily connected with the neural tube in the region of the angle between the alar and basal laminæ.

6. The nerve roots are divisible into two series:—

(*a*) A dorsal series, which pass partly into the cellular portion of the neural tube and partly into the white columns in the region of the ascending roots of the vagus and glosso-pharyngeal nerves. These roots are from twelve to fifteen in number, and in the region of the spinal accessory nerve they appear to terminate almost entirely in the cellular wall of the neural tube dorsal to the next series of roots.

(*b*) A lateral series, which leave the neural tube either together with, or a short distance ventral to, the dorsal series. Many of these roots pass beneath the ganglionic chain, but others appear to be connected either with the ganglia or the cellular strand which unites them. Centrally these roots are connected with the dorsal angle of a column of cells situated along the ventro-lateral aspect of the neural tube, which ultimately becomes the anterior grey cornu and its cephalic continuation. Peripherally they pass, in the region of the second and third somites, into the spinal accessory nerve, and further forward into the stems of the glosso-pharyngeal and vagus nerves. In the region situated between the fourth and eighth somites they pass directly into the spinal accessory nerve, and have no connection with the ganglia of the cervical nerves.

7. The cellular commissure, which in the early stages can be traced backwards beyond the cervical region, terminates in the later stages as a continuous cord, at the second cervical ganglion, but traces of it can be found much further backwards.

8. The dorsal roots of the cervical ganglia enter the cord on the same level as the dorsal roots of the accessory and vagus nerves, and terminate, like the dorsal roots of the vagus, partly in the white columns and partly in the cells which are afterwards situated at the region of the base of the posterior grey horns.

9. The hypo-glossal roots spring from the ventro-lateral angle of the neural tube, taking origin from the column of cells which in the cervical and post-cervical regions becomes converted into the anterior grey cornu.

The most anterior rootlets are collected into a small bundle which lies in front of the first somite. The remaining rootlets are gathered into three bundles, one of which lies in relation with the ventral portion of each of the three first somites, and below the level of the somites all four bundles are collected into one trunk.

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4. *On Cranial Ganglia.* *By* Professor J. Cossar Ewart, *M.D., F.R.S.E.*

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5. *Renewed Experiments on the Modification of the Colours of Lepidopterous Pupæ.* *By* E. B. Poulton, *F.R.S.*

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6. *An Observation bearing on the Non-transmission of Characters required by certain Pupæ.* *By* E. B. Poulton, *F.R.S.*

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7. *On the Cerebral Commissures in the Marsupialia and Monotremata.*[1] *By* Johnson Symington, *M.D., F.R.S.E.*

The author gave an account of the literature of the subject, discussing more particularly the views of Owen and Flower. In 1837 Professor (now Sir Richard) Owen published in the 'Philosophical Transactions' a memoir, On the Structure of the Brain in Marsupial Animals. In this communication it was asserted that the brains of the Marsupialia differed from those of the placental mammals in having no corpus callosum. In 1865 Professor W. H. Flower published a paper in the 'Philosophical Transactions,' in which he controverted the conclusions of Owen, and maintained that a corpus callosum was present in the Marsupialia and Monotremata.

The material used by the author in his study of the subject included the brains of the Ornithorhynchus, Echidna, and various Marsupialia. Serial sections were mounted for microscopic examination and stained with carmine, or by the Weigert-Pal method. Sections were also made for naked-eye examinations upon brains hardened in Müller's fluid.

The conclusions arrived at agreed in general with those of Owen.

In the Marsupialia and Monotremata the anterior commissure is as large as, and generally much larger than, any other transverse commissure of the cerebrum, and it unites the whole of the cortex of the two hemispheres, except the gyri dentati and hippocampi majores. They have no true corpus callosum, and the superior transverse commissure is simply a commissure for the gyri dentati and hippocampi majores—the hippocampal commissure of Owen. The peculiar position of this commissure is due to the fact that the convolutions it unites extend much farther forwards than they do in the placental mammals.

The Monotremata and Marsupialia agree in the general arrangement of their cerebral commissure, and both differ very distinctly from that found in the lower placental mammals so far as examined.

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8. *The Early Development of the Isopod Crustacea.* *By* Professor J. Playfair M'Murrich.

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9. *Note on the Geographical Distribution of Ascidians.* *By* Professor W. A. Herdman, *D.Sc., F.R.S.*

When the large collection of Ascidians, both simple and compound, brought home by the *Challenger* expedition is arranged according to the latitudes where the specimens were collected, it is seen that the great majority belong to the southern hemisphere, and most of them to the far south, such localities as the Straits of Magellan, Kerguelen Island, and Bass Strait being especially rich. Then high northern latitudes follow the extreme south, while tropical and semi-tropical regions are, on the whole, poorly represented. Moreover, the species from these high latitudes were mostly obtained in abundance, and the individuals are mostly of large size, so that not only in number of species, but also in actual mass, the bulk of the collection is from the far south or north. Hence it seems obvious that the Ascidians flourish best in comparatively cold waters.

However, it might seem improbable that the *Challenger* collection, extensive though it is both in species and in localities, would represent the distribution of the group quite adequately and correctly, so I have lately gone over the recorded geographical distribution of all the known species of simple and compound Ascidians, with the result that although, as might be expected, the long-continued and minute investigations of the shores of north-west Europe and the Mediterranean have helped to raise the numbers for temperate seas, still a very considerable

[1] The paper is printed *in extenso* in the *Journal of Anatomy and Physiology* for October 1892.

proportion of the species belong to the extreme north and south, while the tropical Ascidian fauna is relatively scanty and the individuals of small size.

The gigantic *Molgulidæ* (the largest of simple Ascidians), such as *Ascopera gigantea*, *A. pedunculata*, and *Molgula gigantea*, are only known from the far south; the large *Boltenias* are from the north and the south, while to take an example from nearer home, the small *Styelas* of our seas are represented on the northern coasts of Europe and Asia, and in the Greenland seas, by large specimens of *Styela rustica* and *S. monoceros*.

Then in regard to the abundance of individuals, I know of no records of great hauls from tropical seas, while in the Straits of Magellan the *Challenger* obtained about forty specimens of one large species (*Molgula gigantea*), and a dozen of another (*Ascidia Challengeri*), at Kerguelen Island, and large numbers of *Amaroucium variabile* and other compound Ascidians were also obtained, and last summer, while dredging from Mr. Alfred Holt's yacht *Argo*, about eleven miles north of the North Cape, I brought up a dredge net about 3 feet by 1 foot, and about 3 feet long, crammed to the mouth with splendid specimens of the two closely allied species *Styela rustica* and *S. monoceros;* there must have been many hundreds—perhaps thousands. We only picked out and preserved what seemed a few of the better specimens, the remainder being shovelled overboard, and yet I find that about 300 were kept. These large species must evidently be present in enormous profusion at the bottom in some places.

On the whole, then, I consider that this more extended survey of the group points to the same general conclusion which I arrived at from an examination of the *Challenger* collection—viz., that Ascidians attain their greatest development both in numbers and size in the colder northern and southern seas.

Although certain genera seem, with our present knowledge, restricted to particular regions, none of the more important families is confined to northern or southern seas or to the tropics. I have lately received from the Australian coast members of the *Botryllidæ*, a family not previously recorded from southern seas.

The examination lately of two collections of Ascidians from the north of Norway and Finmark, made, the one by Canon Norman and the other by myself, from the *Argo*, recalled vividly the apparent abundance of Ascidians in these northern waters, and caused me to look into the records bearing on the matter.

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10. *Note on Atrial, or Circumcloacal, Tentacles in the Tunicata.* *By* Professor W. A. Herdman, *F.R.S.*

In the interesting paper ('Bulletin Scientifique,' July 1892) by Dr. C. Julin, which forms the first part of his 'Les Ascidiens des Côtes du Boulonnais,' I notice it is stated, on page 30, 'L'existence d'une couronne de tentacules circumcloacaux n'a jamais, à ma connaissance du moins, été signalée chez aucune espèce d'ascidien simple ou composé.' If it has escaped Julin's attention that I described and figured atrial tentacles in 1882 in a simple ascidian, and in 1886 in a compound one, then I fear it may have escaped notice altogether, perhaps because, along with some other anatomical observations and some theoretical conclusions and suggestions, it is buried in the *Challenger* reports in a mass of detailed descriptions of new species. At any rate, the existence of atrial tentacles is evidently so little known that this brief note upon what I have seen of them may be of interest.

In the simple ascidian *Bathyoncus mirabilis* from the Southern Ocean, at a depth of 1,600 fathoms, there are two circlets of minute tentacular processes which project from the inner surface of the cloacal wall close to the atrial aperture. These atrial tentacles are all of the same size, and are placed at about their own length apart (*see* 'Rep. Tun. Chall. Exp.,' part 1, vol. vi. 1882, page 167, and pl. xxiv. fig. 12, *at. t.*).

The ascidiozooids of the compound (?) ascidian, *Goodsiria placenta*, from the Cape of Good Hope, have also atrial tentacles, very much like those of *Bathyoncus*

mirabilis, but forming a single series. In the original description (*op. cit.*, part 2, vol. xiv. 1886, page 331, and pl. xliii. fig. 10) I wrote as follows: 'At the base of the atrial siphon, where the invaginated layer of test ends, there is a slight ridge which bears a series of small tentacles projecting freely into the peribranchial cavity. These atrial tentacles are much smaller than the ordinary or branchial tentacles, and there are only twelve of them. The position of the atrial tentacles in relation to the atrial siphon corresponds exactly to the position of the branchial tentacles at the base of the branchial siphon, but their use at the entrance to the peribranchial cavity is not obvious. It has been observed in some simple ascidians that the current of water which usually flows in at the branchial aperture and out at the atrial is occasionally reversed for a short period, the atrial aperture becoming inhalent. Possibly in the present species this habit may have become so marked as to have favoured the development of a circle of atrial tentacles, which would act as tactile organs waving in the current of water entering the animal.'

During the last few years I have found similar atrial tentacles in at least three new species of the compound (?) ascidian genus *Chorizocormus*, viz., *Ch. sydneyensis*, *Ch. leucophæus*, and *Ch. subfuscus*, all from Australia. In each case they form a single circlet, as in *Goodsiria placenta*, and there are about twenty tentacles. They are briefly referred to in my 'Revised Classification of the Tunicata' (1891), at page 636, and will be figured in the forthcoming 'Catalogue of Tunicata in the Australian Museum.' And, lastly, Julin has made the interesting discovery that atrial tentacles are also present in *Styelopsis grossularia*.

I have queried above the genera *Goodsiria* and *Chorizocormus* as being compound ascidians because they belong to the family Polystyelidæ, in regard to which it must be considered still doubtful whether the masses of ascidiozooids are true colonies. But although they may be colonial forms now, there can be no doubt that phylogenetically the Polystyelidæ are closely related to the sub-family Styelinæ of the Cynthidæ, the sub-family to which both *Bathyoncus* and *Styelopsis* belong. So we arrive at the interesting conclusion that the four genera in which up to now atrial tentacles have been noticed, although differing widely from one another in appearance, structure, and habitat, are yet phylogenetically rather closely related. I think it not unlikely that atrial tentacles will be found, if looked for, in other members of the groups Styelinæ and Polystyelidæ.

Another point: it is an interesting fact, and may have some significance, that—putting aside *Bathyoncus mirabilis*, in regard to the conditions of life of which we know nothing—all the five species in which atrial tentacles have as yet been demonstrated form either colonies or aggregations, *i.e.*, they have numbers of small individuals or ascidiozooids massed together. It is quite conceivable that, under these crowded conditions, it may be some advantage to the animals to have the power (to return to the suggestion I made in the *Challenger* Report) of frequently reversing the current of water or of using the atrial for a time as the inhalent aperture—possibly, for example, because of being so placed amongst neighbours that the atrial siphon is able to draw upon a purer supply of water—and in any such case the advantage of having the entrance to the peribranchial cavity provided with a circlet of tentacles is obvious.

Possibly Julin, in his recent investigations on *Styelopsis grossularia*, has already solved the problem of the meaning and use of the atrial tentacles, and may be able either to support or demolish the above suggestion. In any case I shall be much interested to learn his views on the matter.

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11. *Notes on Lampreys and Hags.* By J. Beard, *M.Sc.*, *Ph.D.*

Two small specimens of *Myxine glutinosa* were described. The one measured 6·5 centimetres, the other 15 centimetres. It was stated that an Ammocœte stage appeared to be unrepresented in Myxine, but that the individual underwent a metamorphosis, as was proved by the 'diphyodont' dentition.

In the smaller specimen the external characters were those of the adult, but the internal anatomy revealed among other things several rows of teeth in both roof

and floor of mouth, and a functional pronephros. The testes of a specimen of Petromyzon planere described were stated to be hermaphrodite, in that here and there in the testis single ova could be found. A section of such a testis with ova was exhibited.

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12. *On the Skeleton and Teeth of the Australian Dugong.*[1]
By Professor G. B. Howes *and* J. Harrison.

The authors showed that the vertebral epiphyses are more fully developed than Albrecht has suspected, and that they appear late and rapidly ankylose with the centra—a feature of especial interest, in view of Lefèvre's alleged discovery of fully developed epiphyses in *Halitherium Schinzi* and *Metaxytherium*. On comparison with the Cetacea, they sought to associate the reduction of the epiphyses with adaptation to an aquatic existence.

In dealing with the limb-skeleton, they described a longitudinal cleavage of the phalanges, akin to that recorded by Kükenthal for the Cetacea. The only structures observed which were at all comparable to supernumerary phalanges were derivatives of the terminal (ungual) ones, arising proximally; and the observations lend no support to Kükenthal's view that supernumerary phalanges are epiphysial in origin.

The first upper incisor and the four lower ones of either side were shown to have milk predecessors, which are early absorbed. Five teeth were shown to be present on either side of the symphysial region of each mandibular ramus of *Manatus*, the fifth one being claimed as a canine; and, in this animal, the authors described milk predecessors to the two anterior pairs of mandibular cheek teeth. The authors finally discussed the bearings of the facts upon the interrelationships and affinities of the Sirenia, for whose presumed incisors a numerical parallel alone exists in the Marsupialia and Soricidæ.

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13. *Can Spiders Prognosticate Weather Changes?*
By Dr. M'Cook.

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14. *Some Notes on Marine and Fresh Water Chironomus.*
By G. Swainson.

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15. *The Earthworms of Great Britain.*
By the Rev. Hilderic Friend, *F.L.S.*

We are indebted to the lamented Charles Darwin for any enthusiasm which has been aroused among the public in the subject of earthworms. The angler, however, was the pioneer student of terrestrial annelids, and to those who use the rod we owe most of our popular names for earthworms. The first and only list yet published in England appeared in 1865, though many able monographs have appeared on the Continent. In 1881 Darwin assumed the existence of eight or ten species of earthworms in England, and I have now to report the progress which has been made in the subject since the publication of 'Vegetable Mould.' In former times all our indigenous worms were ranged under the simple genus *Lumbricus*, but in 1873 Eisen showed that they really belonged to four different genera. He named them *Lumbricus*, *Allolobophora*, *Allurus*, and *Dendrobæna*, but the latter term has fallen into disuse, though I hope to show the wisdom of reviving it for the true tree worms. The genus *Lumbricus*, as understood since Eisen's time, first claims attention. It is distinguished by the 'mortise and tenon' arrangement of the head, the distribution of the setæ in four couples, the indi-

[1] *Apropos* of a Report by the Authors, upon the Sirenia collected by Professor A. C. Haddon in the Torres Straits, to be shortly published in the *Trans. Roy. Dublin Soc.*

viduals of which are always close together; the girdle of six segments, the innermost four of which carry the puberty band; and certain internal peculiarities of a somewhat complex nature. Four true and one abnormal species are now on record for these islands, as follows:—

1. The True Earthworm (*L. terrestris*, Linn.), which has only very recently been properly defined, but may now be infallibly distinguished by its colour, the position of the setæ, the shape of the tail—which is flattened to enable it to grip its burrow—and especially the position of the girdle on segments 32 to 37.

2. The Ruddy Worm (*L. rubescens*, Friend).—New, not only to England, but to science, and recognised by the fact that its girdle commences on the thirty-fourth and ends on the thirty-ninth segment. By this means, as well as by the prominence of the male pores, it is easily distinguished from the next, which it closely resembles in size and colour.

3. The Red Worm (*L. rubellus*, Hoffmeister) is the commonest representative of the genus, and has the twenty-seventh to the thirty-second segments occupied by the girdle.

4. The Purple Worm (*L. purpureus*, Eisen) is usually much smaller than any of the foregoing, though it exactly corresponds with them in colour, shape, and general appearance. Its girdle extends from the twenty-eighth to the thirty-third segment.

5. Eisen's Worm (*L. Eiseni*, Levinsen), though inserted here, cannot be regarded as a true member of the genus, as it lacks several of the characters of the type. It is a very small worm, which frequently lives in decaying timber, and has its girdle on the twenty-fourth to the thirty-first or thirty-second segment, without the usual band on the under surface. I refer it to group No. 4 below.

As its name implies, the genus *Allolobophora* is distinguished by the shape of its lobe-insertion. The colour also is more variable than in *Lumbricus*, while the setæ are not always in pairs, and the girdle occupies an indefinite number of segments, on which the pores or bands, if present, are variously disposed. The genus is best studied in groups, of which we have five in our fauna. Group No. 1 is represented by the Long Worm (*A. longa*, Ude), which has been the cause of endless confusion, owing to its wide dispersion and general similarity to the earthworm. Its specific nature was only determined half a dozen years ago.

Group No. 2 contains a species or sub-species new to science, and found at present only in Dublin (*A. hibernica*, Friend), so far as Great Britain is concerned. It has, however, been simultaneously found on the Continent, but no printed account has yet appeared. The well-known Brandling (*A. fœtida*, Sav.) also belongs to this group, and a search in the Highlands might yield one or two new species.

Group No. 3 has always presented great difficulties, which are now, however, cleared away. The Turgid Worm (*A. turgida*, Eisen) and the Trapeze Worm (*A. trapezoidea*, Dugès) are difficult to distinguish. Midway between the Mucous Worm (*A. mucosa*, Eisen) and the Green Worm (*A. chlorotica*, Savigny) we have to place the newly discovered Welsh Worm (*A. cambrica*, Friend), whose specific differences are only to be recognised by dissection.

Group No. 4 contains several worms which are truly dendrobænic or tree-haunting. They are usually very small, and have their setæ in eight almost equidistant rows. The Gilt-tail (*A. subrubicunda*, Eisen) is the best known, and closely related to this is the Compressed Worm (*A. constricta*, Rosa), which has hitherto been taken by me only in the extreme South of England. The genuine Tree Worm (*A. arborea*, Eisen) lives in the very heart of damp, decaying timber, and is often associated with the Celtic Worm (*A. celtica*, Rosa), which, however, keeps near the bark, or lies in the soil underneath the wood. The type of Eisen's genus *Dendrobæna* (*D. boeckii*, Eisen) may for the present be put here. It has only been met with in Yorkshire and near Paisley, so far as my authenticated records go at present. *L. Eiseni*, Lev., is very closely related to the members of this group.

Group No. 5 may be known by the large size of its members, whose setæ, unlike those of other large species, are wide apart. The Roving Worm (*A. profuga*, Rosa) has this year been added to our English lists, and another species (*A. com-*

planata, Dugès), which is the only one I have not personally studied, is recorded on the strength of a recent memoir.

There remains the genus *Allurus*, which is readily distinguished by its square tail and semi-aquatic habit. Its male pores also are on the thirteenth segment, and there are only two or three species at present known to science. Of these, the Square Tail (*A. tetrædrus*, Savigny), the Quadrangular (*A. tetragonurus*, Friend), and the Golden Worm (*A. flavus*, Friend) are indigenous, and there are also some interesting varieties.

The generic differences are best understood by presenting the main features in the form of a chart which was exhibited to the Section, and a complete list of all the species at present known to occur in Great Britain is given in the paper.

A wide field for research is opened up by the study of earthworms. Their distribution, numbers, and utility; the height to which they ascend, the habitats they prefer, the parasites by which they are infested, the freaks and abnormalities to which they are liable, are only a few of the many topics which may be profitably studied, and concerning which I have for some years past been busily accumulating a mass of interesting material.

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16. *The Human Body as a Conductor of Electricity.* *By* H. Newman Lawrence.

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17. *Fertilisation of the Eggs of the Stickleback.* *By* Professor J. B. Haycraft.

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18. *On the Canalisation of Cells and the Continuity of Living Matter in Plants and Animals.* *By* Dr. Louis Olivier, *Editor of the 'Revue générale des Sciences pures et appliquées.'*

1. We have long known that both in animals and plants certain cells, instead of being completely closed, present in their walls pores which establish a communication between the cellular cavities. These cases have been especially observed in organisms of a lower type (as, for instance, in the Siphonocladaceæ Algæ), which form, as it were, a connecting link between uni-cellular and multi-cellular forms. In the latter, however, special groups of cells have been described, which communicate by their extremities. Such, for instance, are the sieve tubes of the liber discovered by Hartig, the endosperm cells of certain monocotyledons observed by Tangl, the cells of the pulvinus of the petiole of the sensitive plant and other tissues specially described by Gardiner, &c.

These instances of cellular canalisation were considered till recent years as exceptional in the tissues of living organisms, where they seemed to be of strictly local occurrence; so that the cell in the higher animals and plants was still looked on as a completely closed chamber; the cavity either containing or free from protoplasm could only have osmotic communication with its fellows.

2. In 1885 I was led to suspect that this theory was erroneous, and to recognise even in highly differentiated tissues and in highly organised individuals the canalisation of the cell-wall and the free passage of protoplasm through the narrow pores.

On photographing under special conditions three sections of various tissues, artificially stained, I was surprised to see on the plates a very remarkable arrangement in the cell-walls, which direct observation had failed to reveal. I attributed this result to the fact that optical and chemical conditions in photography are in various respects different from those in direct vision, and I believed it possible to base on this observation a method of research supplementary to simple microscopical examination. The proofs I have obtained confirm this anticipation.

3. In order to see directly the canalisation of the cells under the microscope, we must use reagents capable of giving us a double stain.

We cannot, however, make use of this method in all cases, for when the tissues in which we wish to observe the protoplasm are living, reagents induce a contraction of the protoplasm into the cell-cavities and the rupture of the exceedingly fine filaments which unite a cell to its fellows. To force, as it were, these filaments to remain in position, I thought it desirable to produce a slow anæsthesis of the tissues before fixing, hardening, cutting, and staining them. Osmic acid, which anatomists often use, can be of no service to me, as it does not attack simultaneously the various portions of the protoplasm surrounded by their cell-wall, and, moreover, nearly always renders staining impossible at a later stage. I therefore had recourse to true anæsthetic agents, ether, chloroform, carbon disulphide, &c.

The organism should be submitted in its entirety to the action of the vapours of these reagents. When it has quite 'gone to sleep,' a fragment of the tissue may be detached, plunged into alcohol containing picric acid, and then cut into sections of $\frac{1}{200}$ of a millimetre in thickness; if they are vegetable tissues, they must be treated with dilute selenic acid, washed and double-stained.

The cellular membranes, already much thinned out and partly destroyed by the selenic acid, are seen to be coloured red, for instance, while the protoplasmic filaments which pass through them are coloured blue, like the protoplasm of the cell-cavities, and are seen to be in continuity therewith.

This method has allowed me to ascertain that in highly organised species, such as Dicotyledons, the protoplasm is continuous from the extremity of the roots to the extremities of the leaves. The protoplasm is differentiated in these various regions, and exhibits many various properties, but remains everywhere in a state of continuity.

4. It seemed to me that the method for photographing doubly coloured originals, devised last year by MM. A. et L. Lumière (of Lyon), would make this structure easily visible. By photographing my preparations according to this method, I have obtained examples on glass, showing the fine filaments of protoplasm coloured blue clearly distinguished from the cell-wall membrane, which is coloured red.

The following Demonstrations were exhibited in the Microscopical Room of the Physiological Department from 2 to 4:—

1. Mr. Albert F. Calvert.—The Formation of Pearls.
2. Mr. E. W. L. Holt.—Interesting British Food Fishes.
3. Prof. M. Hartog.—Dividing Pollen Mother Cells.
4. Dr. Carlier.—Hiberating Gland of Hedgehog.
5. Mr. Goodchild.—Wings of Birds.
6. Dr. G. Mann.—Embryo-sac of Angiosperms.
7. Mr. A. C. Seward.—Structure of Myeloxylon.

Section E.—GEOGRAPHY.

President of the Section—Professor James Geikie, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S.

THURSDAY, AUGUST 4.

The President delivered the following address:—

Amongst the many questions upon which of late years light has been thrown by deep-sea exploration and geological research, not the least interesting is that of the geographical development of coast-lines. How is the existing distribution of land and water to be accounted for? Are the revolutions in the relative position of land and sea, to which the geological record bears witness, due to movements of the earth's crust or of the hydrosphere? Why are coast-lines in some regions extremely regular, while elsewhere they are much indented? About 150 years ago the prevalent belief was that ancient sea-margins indicated a formerly higher ocean-level. Such was the view held by Celsius, who, from an examination of the coast-lands of Sweden, attributed the retreat of the sea to a gradual drying up of the latter. But this desiccation hypothesis was not accepted by Playfair, who thought it much more likely that the land had risen. It was not, however, until after Von Buch had visited Sweden (1806–1808), and published the results of his observations, that Playfair's suggestion received much consideration. Von Buch concluded that the apparent retreat of the sea was not due to a general depression of the ocean-level, but to elevation of the land—a conclusion which subsequently obtained the strong support of Lyell. The authority of these celebrated men gained for the elevation theory more or less complete assent, and for many years it has been the orthodox belief of geologists that the ancient sea-margins of Sweden and other lands have resulted from vertical movements of the crust. It has long been admitted, however, that highly flexed and disturbed strata require some other explanation. Obviously such structures are the result of lateral compression and crumpling. Hence geologists have maintained that the mysterious subterranean forces have affected the crust in different ways. Mountain-ranges, they conceive, are ridged up by tangential thrusts and compression, while vast continental areas slowly rise and fall, with little or no disturbance of the strata. From this point of view it is the lithosphere that is unstable, all changes in the relative level of land and sea being due to crustal movements. Of late years, however, Trautschold and others have begun to doubt whether this theory is wholly true, and to maintain that the sea-level may have changed without reference to movements of the lithosphere. Thus Hilber has suggested that sinking of the sea-level may be due, in part at least, to absorption, while Schmick believes that the apparent elevation and depression of continental areas are really the results of grand secular movements of the ocean. The sea, according to him, periodically attains a high level in each hemisphere alternately, the waters being at present heaped up in the southern hemisphere. Professor Suess, again, believing that in equatorial regions the sea is, upon the whole, gaining on the land, while

in other latitudes the reverse would appear to be the case, points out that this is in harmony with his view of a periodical flux and reflux of the ocean between the equator and the poles. He thinks that we have no evidence of any vertical elevation affecting wide areas, and that the only movements of elevation that take place are those by which mountains are upheaved. The broad invasions and transgressions of the continental areas by the sea, which we know have occurred again and again, are attributed by him to secular movements of the hydrosphere itself.

Apart from all hypothesis and theory, we learn that the surface of the sea is not exactly spheroidal. It reaches a higher level on the borders of the continents than in mid-ocean, and it varies likewise in height at different places on the same coast. The attraction of the Himalaya, for example, suffices to cause a difference of 300 feet between the level of the sea at the delta of the Indus and on the coast of Ceylon. The recognition of such facts has led Penck to suggest that the submergence of the maritime regions of North-west Europe and the opposite coasts of North America, which took place at a recent geological date, and from which the lands in question have only partially recovered, may have been brought about by the attraction exerted by the vast ice-sheets of the Glacial period. But, as Drygalski, Woodward, and others have shown, the heights at which recent marine deposits occur in the regions referred to are much too great to be accounted for by any possible distortion of the hydrosphere. The late James Croll had previously endeavoured to show that the accumulation of ice over northern lands during Glacial times would suffice to displace the earth's centre of gravity, and thus cause the sea to rise upon the glaciated tracts. More recently other views have been advanced to explain the apparently causal connection between glaciation and submergence, but these need not be considered here.

Whatever degree of importance may attach to the various hypotheses of secular movements of the sea, it is obvious that the general trends of the world's coast-lines are determined in the first place by the position of the dominant wrinkles of the lithosphere. Even if we concede that all 'raised beaches,' so called, are not necessarily the result of earth-movements, and that the frequent transgressions of the continental areas by oceanic waters in geological times may possibly have been due to independent movements of the sea, still we must admit that the solid crust of the globe has always been subject to distortion. And this being so, we cannot doubt that the general trends of the world's coast-lines must have been modified from time to time by movements of the lithosphere.

As geographers we are not immediately concerned with the mode of origin of those vast wrinkles, nor need we speculate on the causes which may have determined their direction. It seems, however, to be the general opinion that the configuration of the lithosphere is due simply to the sinking-in and crumpling-up of the crust on the cooling and contracting nucleus. But it must be admitted that neither physicists nor geologists are prepared with a satisfactory hypothesis to account for the prominent trends of the great world-ridges and troughs. According to the late Professor Alexander Winchell, these trends may have been the result of primitive tidal action. He was of opinion that the transmeridional progress of the tidal swell in early incrustive times on our planet would give the forming crust structural characteristics and aptitudes trending from north to south. The earliest wrinkles to come into existence, therefore, would be meridional or submeridional, and such, certainly, is the prevalent direction of the most conspicuous earth-features. There are many terrestrial trends, however, as Professor Winchell knew, which do not conform to the requirements of his hypothesis; but such transmeridional features, he thought, could generally be shown to be of later origin than the others. This is the only speculation, so far as I know, which attempts, perhaps not altogether unsuccessfully, to explain the origin of the main trends of terrestrial features. According to other authorities, however, the area of the earth's crust occupied by the ocean is denser than that over which the continental regions are spread. The depressed denser part balances the lighter elevated portion. But why these regions of different densities should be so distributed no one has yet told us. Neither does Le Conte's view, that the continental areas and

the oceanic depressions owe their origin to unequal radial contraction of the earth in its secular cooling, help us to understand why the larger features of the globe should be disposed as they are.

Geographers must for the present be content to take the world as they find it. What we do know is that our lands are distributed over the surface of a great continental plateau of irregular form, the bounding slopes of which plunge down more or less steeply into a vast oceanic depression. So far as geological research has gone, there is reason to believe that these elevated and depressed areas are of primeval antiquity—that they antedate the very oldest of the sedimentary formations. There is abundant evidence, however, to show that the relatively elevated or continental area has been again and again irregularly submerged under tolerably deep and wide seas. But all historical geology assures us that the continental plateau and the oceanic hollows have never changed places, although from time to time portions of the latter have been ridged up and added to the margins of the former, while ever and anon marginal portions of the plateau have sunk down to very considerable depths. We may thus speak of the great world-ridges as regions of dominant elevation, and of the profound oceanic troughs as areas of more or less persistent depression. From one point of view, it is true, no part of the earth's surface can be looked upon as a region of dominant elevation. Our globe is a cooling and contracting body, and depression must always be the prevailing movement of the lithosphere. The elevation of the continental plateau is thus only relative. Could we conceive the crust throughout the deeper portions of the oceanic depression to subside to still greater depths, while at the same time the continental plateau remained stationary, or subsided more slowly, the sea would necessarily retreat from the land, and the latter would then appear to rise. It is improbable, however, that any extensive subsidence of the crust under the ocean could take place without accompanying disturbance of the continental plateau; and in this case the latter might experience in places not only negative but positive elevation. During the evolution of our continents, crustal movements have again and again disturbed the relative level of land and sea, but since the general result has been to increase the land surface and to contract the area occupied by the sea, it is convenient to speak of the former as the region of dominant elevation, and of the latter as that of prevalent depression. Properly speaking, both are sinking regions, the rate of subsidence within the oceanic trough being in excess of that experienced over the continental plateau. The question of the geographical development of coast-lines is therefore only that of the dry lands themselves.

The greater land masses are all situated upon, but are nowhere co-extensive with, the area of dominant elevation, for very considerable portions of the continental plateau are still covered by the sea. Opinions may differ as to which fathoms-line we should take as marking approximately the boundary between that region and the oceanic depression; and it is obvious, indeed, that any line selected must be arbitrary and more or less misleading, for it is quite certain that the true boundary of the continental plateau cannot lie parallel to the surface of the ocean. In some regions it approaches within a few hundreds of fathoms of the sea-level; in other places it sinks for considerably more than 1,000 fathoms below that level. Thus, while a very moderate elevation would in certain latitudes cause the land to extend to the edge of the plateau, an elevation of at least 10,000 feet would be required in some other places to bring about a similar result.

Although it is true that the land surface is nowhere co-extensive with the great plateau, yet the existing coast-lines may be said to trend in the same general direction as its margins. So abruptly does the continental plateau rise from the oceanic trough, that a depression of the sea-level, or an elevation of the plateau, for 10,000 feet would add only a narrow belt to the Pacific coast between Alaska and Cape Horn, while the gain of land on the Atlantic slope of America between 30° N. lat. and 40° S. lat. would not be much greater. In the higher latitudes of the Northern Hemisphere, however, very considerable geographical changes would be accomplished by a much less amount of elevation of the plateau. Were the continental plateau to be upheaved for 3,000 feet, the major portion of the Arctic Sea would become land. Thus, in general terms, we may say that the coast-lines

of Arctic and temperate North America and Eurasia are further withdrawn from the edge of the continental plateau than those of lower latitudes.

In regions where existing coast-lines approach the margin of the plateau, they are apt to run for long distances in one determinate direction, and, whether the coastal area be high or not, to show a gentle sinuosity. Their course is seldom interrupted by bold projecting headlands or peninsulas, or by intruding inlets, while fringing or marginal islands rarely occur. To these appearances the northern regions, as everyone knows, offer the strongest contrast. Not only do they trend irregularly, but their continuity is constantly interrupted by promontories and peninsulas, by inlets and fiords, while fringing islands abound. But an elevation of some 400 or 500 fathoms only would revolutionise the geography of those regions, and confer upon the northern coast-lines of the world the regularity which at present characterises those of Western Africa.

It is obvious, therefore, that the coast-lines of such lands as Africa owe their regularity primarily to their approximate coincidence with the steep boundary slopes of the continental plateau, while the irregularities characteristic of the coast-line of North-western Europe and the corresponding latitudes of North America are determined by the superficial configuration of the same plateau, which in those regions is relatively more depressed. I have spoken of the general contrast between high and low northern latitudes, but it is needless to say that in southern regions the coast-lines exhibit similar contrasts. The regular coast-lines of Africa and South America have already been referred to, but we cannot fail to recognise in the much indented sea-board and the numerous coastal islands of Southern Chili a complete analogy to the fiord regions of high northern latitudes. Both are areas of comparatively recent depression. Again, the manifold irregularities of the coasts of South-eastern Asia, and the multitudes of islands that serve to link that continent to Australia and New Zealand, are all evidence that the surface of the continental plateau in those regions is extensively invaded by the sea.

A word or two now as to the configuration of the oceanic trough. There can be no doubt that this differs very considerably from that of the land surface. It is, upon the whole, flat or gently undulating. Here and there it swells gently upwards into broad elevated banks, some of which have been traced for great distances. In other places narrower ridges and abrupt mountain-like elevations diversify its surface, and project again and again above the level of the sea, to form the numerous islets of Oceania. Once more, the sounding-line has made us acquainted with the notable fact that numerous deep depressions—some long and narrow, others relatively short and broad—stud the floor of the great trough. I shall have occasion to refer again to these remarkable depressions, and need at present only call attention to the fact that they are especially well-developed in the region of the Western Pacific, where the floor of the sea, at the base of the bounding slopes of the continental plateau, sinks in places to depths of three and even of five miles below the existing coast-lines. One may further note the fact that the deepest areas of the Atlantic are met with in like manner close to the walls of the plateau—a long ridge, which rises midway between the continents and runs in the same general direction as their coast-lines, serving to divide the trough of the Atlantic into two parallel hollows.

But, to return to our coast-lines and the question of their development, it is obvious that their general trends have been determined by crustal movements. Their regularity is in direct proportion to the closeness of their approach to the margin of the continental plateau. The more nearly they coincide with the edge of that plateau, the fewer irregularities do they present; the further they recede from it, the more highly are they indented. Various other factors, it is true, have played a more or less important part in their development, but their dominant trends were undoubtedly determined at a very early period in the world's history—their determination necessarily dates back, in short, to the time when the great world-ridges and oceanic troughs came into existence. So far as we can read the story told by the rocks, however, it would seem that in the earliest ages of which geology can speak with any confidence the coast-lines of the world must have been infinitely more irregular than now. In Palæozoic times relatively small areas of

the continental plateau appeared above the level of the sea. Insular conditions everywhere prevailed. But as ages rolled on wider and wider tracts of the plateau were exposed, and this notwithstanding many oscillations of level. So that one may say there has been upon the whole a general advance from insular to continental conditions. In other words, the sea has continued to retreat from the surface of the continental plateau. To account for this change we must suppose that depression of the crust has been in excess within the oceanic area, and that now and again positive elevation of the continental plateau has taken place, more especially along its margins. That movements of elevation, positive or negative, have again and again affected our land areas can be demonstrated, and it seems highly probable, therefore, that similar movements may have been experienced within the oceanic trough.

Two kinds of crustal movement, as we have seen, are recognised by geologists. Sometimes the crust appears to rise, or, as the case may be, to sink over wide regions, without much disturbance or tilting of strata, although these are now and again more or less extensively fractured and displaced. It may conduce to clearness if we speak of these movements as regional. The other kind of crustal disturbance takes place more markedly in linear directions, and is always accompanied by abrupt folding and mashing together of strata, along with more or less fracturing and displacement. The plateau of the Colorado has often been cited as a good example of regional elevation, where we have a wide area of approximately horizontal strata apparently uplifted without much rock-disturbance, while the Alps or any other chain of highly flexed and convoluted strata will serve as an example of what we may term axial or linear uplifts. It must be understood that both regional and axial movements result from the same cause—the adjustment of the solid crust to the contracting nucleus—and that the term *elevation*, therefore, is only relative. Sometimes the sinking crust gets relief from the enormous lateral pressure to which it is subjected by crumpling up along lines of weakness, and then mountains of elevation are formed; at other times, the pressure is relieved by the formation of broader swellings, when wide areas become uplifted relatively to surrounding regions. Geologists, however, are beginning to doubt whether upheaval of the latter kind can affect a broad continental area. Probably, in most cases, the apparent elevation of continental regions is only negative. The land appears to have risen because the floor of the oceanic basin has become depressed. Even the smaller plateau-like elevations which occur within some continental regions may in a similar way owe their dominance to the sinking of contiguous regions.

In the geographical development of our land movements of elevation and depression have played an important part. But we cannot ignore the work done by other agents of change. If the orographical features of the land everywhere attest the potency of plutonic agents, they no less forcibly assure us that the inequalities of surface resulting from such movement are universally modified by denudation and sedimentation. Elevated plains and mountains are gradually demolished, and the hollows and depressions of the great continental plateau become slowly filled with their detritus. Thus inland seas tend to vanish, inlets and estuaries are silted up, and the land in places advances seaward. The energies of the sea, again, come in to aid those of rain and rivers, so that under the combined action of all the superficial agents of change the irregularities of coast-lines become reduced, and, were no crustal movement to intervene, would eventually disappear. The work accomplished by those agents upon a coast-line is most conspicuous in regions where the surface of the continental plateau is occupied by comparatively shallow seas. Here full play is given to sedimentation and marine erosion, while the latter alone comes into prominence upon shores that are washed by deeper waters. When the coast-lines advance to the edge of the continental plateau, they naturally trend, as we have seen, for great distances in some particular direction. Should they preserve that position, undisturbed by crustal oscillation, for a prolonged period of time, they will eventually be cut back by the sea. In this way a shelf or terrace will be formed, narrow in some places, broader in others, according to the resistance offered by the varying character of

the rocks. But no long inlets or fiords can result from such action. At most the harder and less readily demolished rocks will form headlands, while shallow bays will be scooped out of the more yielding masses. In short, between the narrower and broader parts of the eroded shelf or terrace a certain proportion will tend to be preserved. As the shelf is widened, sedimentation will become more and more effective, and in places may come to protect the land from further marine erosion. This action is especially conspicuous in tropical and subtropical regions, which are characterised by well-marked rainy seasons. In such regions immense quantities of sediment are washed down from the land to the sea, and tend to accumulate along shore, forming low alluvial flats. All long-established coast-lines thus acquire a characteristically sinuous form, and perhaps no better examples could be cited than those of Western Africa.

To sum up, then, we may say that the chief agents concerned in the development of coast-lines are crustal movements, sedimentation, and marine erosion. All the main trends are the result of elevation and depression. Considerable geographical changes, however, have been brought about by the silting up of those shallow and sheltered seas which, in certain regions, overflow wide areas of the continental plateau. Throughout all the ages, indeed, epigene agents have striven to reduce the superficial inequalities of that plateau by levelling heights and filling up depressions, and thus, as it were, flattening out the land surface and causing it to extend. The erosive action of the sea, from our present point of view, is of comparatively little importance. It merely adds a few finishing touches to the work performed by the other agents of change.

A glance at the geographical evolution of our own continent will render this sufficiently evident. Viewed in detail, the structure of Europe is exceedingly complicated, but there are certain leading features in its architecture which no profound analysis is required to detect. We note, in the first place, that highly disturbed rocks of Archæan and Palæozoic age reach their greatest development along the north-western and western borders of our continent, as in Scandinavia, the British Islands, North-west France, and the Iberian Peninsula. Another belt of similarly disturbed strata of like age traverses Central Europe from west to east, and is seen in the south of Ireland, Cornwall, North-west France, the Ardennes, the Thüringerwald, the Erzgebirge, the Riesengebirge, the Böhmerwald, and other heights of Middle and Southern Germany. Strata of Mesozoic and Cainozoic age rest upon the older systems in such a way as to show that the latter had been much folded, fractured, and denuded before they came to be covered with younger formations. North and north-east of the central belt of ancient rocks just referred to, the sedimentary strata that extend to the shores of the Baltic and over a vast region in Russia range in age from Palæozoic down to Cainozoic times, and are disposed for the most part in gentle undulations: they are either approximately horizontal or slightly inclined. Unlike the disturbed rocks of the maritime regions and of Central Europe, they have obviously been subjected to comparatively little folding since the time of their deposition. To the south of the primitive backbone of Central Europe succeeds a region composed superficially of Mesozoic and Cainozoic strata for the most part, which, along with underlying Palæozoic and Archæan rocks, are often highly flexed and ridged up, as in the chains of the Jura, the Alps, the Carpathians, &c. One may say, in general terms, that throughout the whole Mediterranean area Archæan and Palæozoic rocks appear at the surface only when they form the nuclei of mountains of elevation into the composition of which rocks of younger age largely enter.

From this bald and meagre outline of the general geological structure of Europe, we may gather that the leading orographical features of our continent began to be developed at a very early period. Unquestionably the oldest land areas are represented by the disturbed Archæan and Palæozoic rocks of the Atlantic sea-board and Central Europe. Examination of those tracts shows that they have experienced excessive denudation. The Archæan and Palæozoic masses, distributed along the margin of the Atlantic, are the mere wrecks of what, in earlier ages, must have been lofty regions, the mountain-chains of which may well have rivalled or even exceeded in height the Alps of to-day. They, together with

the old disturbed rocks of Central Europe, formed for a long time the only land in our area. Between the ancient Scandinavian tract in the North and a narrow interrupted belt in Central Europe stretched a shallow sea, which covered all the regions that now form our Great Plain ; while immediately south of the central belt lay the wide depression of the Mediterranean—for as yet the Pyrenees, the Alps, and the Carpathians were not. Both the Mediterranean and the Russo-Germanic sea communicated with the Atlantic. As time went on land continued to be developed along the same lines, a result due partly to crustal movements, partly to sedimentation. Thus by-and-by the relatively shallow Russo-Germanic sea became silted up, while the Mediterranean shore-line advanced southwards. It is interesting to note that the latter sea, down to the close of Tertiary times, seems always to have communicated freely with the Atlantic, and to have been relatively deep. The Russo-Germanic sea, on the contrary, while now and again opening widely into the Atlantic, and attaining considerable depths in its western reaches, remained on the whole shallow, and ever and anon vanished from wide areas to contract into a series of inland seas and large salt lakes.

Reduced to its simplest elements, therefore, the structure of Europe shows two primitive ridges—one extending with some interruptions along the Atlantic sea-board, the other traversing Central Europe from west to east, and separating the area of the Great Plain from the Mediterranean basin. The excessive denudation which the more ancient lands have undergone, and the great uplifts of Mesozoic and of Cainozoic times, together with the comparatively recent submergence of broad tracts in the north and north-west, have not succeeded in obscuring the dominant features in the architecture of our continent.

I now proceed to trace, as rapidly as I can, the geographical development of the coast-lines of the Atlantic as a whole, and to point out the chief contrasts between them and those of the Pacific. The extreme irregularity of the Arctic and Atlantic shores of Europe at once suggests to a geologist a partially drowned land, the superficial inequalities of which are accountable for the vagaries of the coast-lines. The fiords of Norway and Scotland occupy what were at no distant date land valleys, and the numerous marginal islands of those regions are merely the projecting portions of a recently sunken area. The continental plateau extends up to and a little beyond the 100-fathoms line, and there are many indications that the land formerly reached as far. Thus the sunken area is traversed by valley-like depressions, which widen as they pass outwards to the edge of the plateau, and have all the appearance of being hollows of subaerial erosion. I have already mentioned the fact that the Scandinavian uplands and the Scottish Highlands are the relics of what were at one time true mountains of elevation, corresponding in the mode of their formation to those of Switzerland, and, like these, attaining a great elevation. During subsequent stages of Palæozoic times that highly elevated region was subjected to long-continued and profound erosion —the mountain country was planed down over wide regions to sea-level, and broad stretches of the reduced land surface became submerged. Younger Palæozoic formations then accumulated upon the drowned land, until eventually renewed crustal disturbance supervened, and the marginal areas of the continental plateau again appeared as dry land, but not, as before, in the form of mountains of elevation. Lofty table-lands now took the place of abrupt and serrated ranges and chains—table-lands which, in their turn, were destined in the course of long ages to be deeply sculptured and furrowed by subaerial agents. During this process the European coast-line would seem to have coincided more or less closely with the edge of the continental plateau. Finally, after many subsequent movements of the crust in these latitudes, the land became partially submerged—a condition from which North-western and Northern Europe would appear in recent times to be slowly recovering. Thus the highly indented coast-line of those regions does not coincide with the edge of the plateau, but with those irregularities of its upper surface which are the result of antecedent subaerial erosion.

Mention has been made of the Russo-Germanic plain and the Mediterranean as representing original depressions in the continental plateau, and of the high grounds that extend between them as regions of dominant elevation, which,

throughout all the manifold revolutions of the past, would appear to have persisted as a more or less well-marked boundary, separating the northern from the southern basin. During certain periods it was no doubt in some degree submerged, but never apparently to the same extent as the depressed areas it served to separate. From time to time uplifts continued to take place along this central belt, which thus increased in breadth, the younger formations, which were accumulated along the margins of the two basins, being successively ridged up against nuclei of older rocks. The latest great crustal movements in our continent, resulting in the uplift of the Alps and other east and west ranges of similar age, have still further widened that ancient belt of dominant elevation which in our day forms the most marked orographical feature of Europe.

The Russo-Germanic basin is now for the most part land, the Baltic and the North Sea representing its still submerged portions. This basin, as already remarked, was probably never so deep as that of the Mediterranean. We gather as much from the fact that while mechanical sediments of comparatively shallow-water origin predominate in the former area, limestones are the characteristic features of the southern region. Its relative shallowness helps us to understand why the northern depression should have been silted up more completely than the Mediterranean. We must remember also that for long ages it received the drainage of a much more extensive land surface than the latter, the land that sloped towards the Mediterranean in Palæozoic and Mesozoic times being of relatively little importance. Thus the crustal movements which ever and anon depressed the Russo-Germanic area were, in the long run, counterbalanced by sedimentation. The uplift of the Alps, the Atlas, and other east and west ranges has greatly contracted the area of the Mediterranean, and sedimentation has also acted in the same direction, but it is highly probable that that sea is now as deep as, or even deeper than, it has ever been. It occupies a primitive depression in which the rate of subsidence has exceeded that of sedimentation. In many respects, indeed, this remarkable transmeridional hollow—continued eastward in the Red Sea, the Black Sea, and the Aralo-Caspian depression—is analogous, as we shall see, to the great oceanic trough itself.

In the earlier geological periods linear or axial uplifts and volcanic action again and again marked the growth of the land on the Atlantic sea-board. But after Palæozoic times no great mountains of elevation came into existence in that region, while volcanic action almost ceased. In Tertiary times, it is true, there was a remarkable recrudescence of volcanic activity, but the massive eruptions of Antrim and Western Scotland, of the Færöe Islands and Iceland, must be considered apart from the general geology of our continent. From Mesozoic times onwards it was along the borders of the Mediterranean depression that great mountain uplifts and volcanoes chiefly presented themselves; and as the land surface extended southwards from Central Europe, and the area of the Mediterranean was contracted, volcanic action followed the advancing shore-lines. The occurrence of numerous extinct and of still existing volcanoes along the borders of this inland sea, the evidence of recent crustal movements so commonly met with upon its margins, the great irregularities of its depths, the proximity of vast axial uplifts of late geological age, and the frequency of earthquake phenomena, all indicate instability, and remind us strongly of similarly constructed and disturbed regions within the area of the vast Pacific.

Let us now look at the Arctic and Antarctic coast-lines of North America. From the extreme north down to the latitude of New York the shores are obviously those of a partially submerged region. They are of the same type as the coasts of North-western Europe. We have every reason to believe also that the depression of Greenland and North-east America, from which these lands have only partially recovered, dates back to a comparatively recent period. The fiords and inlets, like those of Europe, are merely half-drowned land valleys, and the continental shelf is crossed by deep hollows which are evidently only the seaward continuations of well-marked terrestrial features. Such, for example, is the case with the valleys of the Hudson and the St. Lawrence, the submerged portions of which can be followed out to the edge of the continental plateau, which is notched

by them at depths of 474 and 622 fathoms respectively. There is, in short, a broad resemblance between the coasts of the entire Arctic and North Atlantic regions down to the latitudes already mentioned. Everywhere they are irregular and fringed with islands in less or greater abundance—highly denuded and deeply incised plateaus being penetrated by fiords, while low-lying and undulating lands that shelve gently seaward are invaded by shallow bays and inlets. Comparing the American with the opposite European coasts one cannot help being struck with certain other resemblances. Thus Hudson Bay at once suggests the Baltic, and the Gulf of Mexico, with the Caribbean Sea, recalls the Mediterranean. But the geological structure of the coast-lands of Greenland and North America betrays a much closer resemblance between these and the opposite shores of Europe than appears on a glance at the map. There is something more than a mere superficial similarity. In eastern North America and Greenland, just as in Western Europe, no grand mountain uplifts have taken place for a prodigious time. The latest great upheavals, which were accompanied by much folding and flexing of strata, are those of the Apallachian chain and of the coastal ranges extending through New England, Nova Scotia, and Newfoundland, all of which are of Palæozoic age. Considerable crustal movements affected the American coast-lands in Mesozoic times, and during these uplifts the strata suffered fracture and displacement, but were subjected to comparatively little folding. Again, along the maritime borders of North-east America, as in the corresponding coast-lands of Europe, igneous action, more or less abundant in Palæozoic and early Mesozoic times, has since been quiescent. From the mouth of the Hudson to the Straits of Florida the coast-lands are composed of Tertiary and Quaternary deposits. This shows that the land has continued down to recent times to gain upon the sea—a result brought about partly by quiet crustal movements, but to a large extent by sedimentation, aided, on the coasts of Florida, by the action of reef-building corals.

Although volcanic action has long ceased on the American sea-board, we note that in Greenland, as in the West of Scotland and North of Ireland, there is abundant evidence of volcanic activity at so late a period as the Tertiary. It would appear that the great plateau-basalts of those regions, and of Iceland and the Færöe Islands, were contemporaneous, and possibly connected with an important crustal movement. It has long been suggested that at a very early geological period Europe and North America may have been united. The great thickness attained by the Palæozoic rocks in the eastern areas of the latter implies the existence of a wide land surface from which ancient sediments were derived. That old land must have extended beyond the existing coast-line, but how far we cannot tell. Similarly in North-west Europe, during early Palæozoic times, the land probably stretched further into the Atlantic than at present. But whether, as some think, an actual land connection subsisted between the two continents it is impossible to say. Some such connection was formerly supposed necessary to account for the emigration and immigration of certain marine forms of life which are common to the Palæozoic strata of both continents, and which, as they were probably denizens of comparatively shallow water, could only have crossed from one area to another along a shore-line. It is obvious, indeed, that if the oceanic troughs in those early days were of an abysmal character, a belt of shallow water would be required to explain the geographical distribution of cosmopolitan marine life-forms. But if it be true that subsidence of the crust has been going on through all geological time, and that the land areas have notwithstanding continued to extend over the continental plateau, then it follows that the oceanic trough must be deeper now than it was in Palæozoic times. There are, moreover, certain geological facts which seem hardly explicable on the assumption that the seas of past ages attained abysmal depths over any extensive areas. The Palæozoic strata which enter so largely into the framework of our lands have much the same appearance all the world over, and were accumulated for the most part in comparatively shallow water. A petrographical description of the Palæozoic mechanical sediments of Europe would serve almost equally well for those of America, of Asia, or of Australia. Take in connection with this the fact that Palæozoic faunas had a

very much wider range than those of Mesozoic and later ages, and were characterised above all by the presence of many cosmopolitan species, and we can hardly resist the conclusion that it was the comparative shallowness of the ancient seas that favoured that wide dispersal of species, and enabled currents to distribute sediments the same in kind over such vast regions. As the oceanic area deepened and contracted, and the land surface increased, marine faunas were gradually restricted in their range, and cosmopolitan marine forms diminished in numbers, while sediments, gathering in separate regions, became more and more differentiated. For these and other reasons, which need not be entered upon here, I see no necessity for supposing that a Palæozoic Atlantis connected Europe with North America. The broad ridge upon which the Færöe Islands and Iceland are founded seems to pertain as truly to the oceanic depression as the long Dolphin Ridge of the South Atlantic. The trend of the continental plateau in high latitudes is shown, as I think, by the general direction of the coast-lines of North-western Europe and East Greenland, the continental shelf being submerged in those regions for a few hundred fathoms only. How the Icelandic ridge came into existence, and what its age may be, we can only conjecture. It may be a wrinkle as old as the oceanic trough which it traverses, or its origin may date back to a much more recent period. We may conceive it to be an area which has subsided more slowly than the floor of the ocean to the north and south; or, on the other hand, it may be a belt of positive elevation. Perhaps the latter is the more probable supposition, for it seems very unlikely that crustal disturbances, resulting in axial and regional uplifts, should have been confined to the continental plateau only. Be that as it may, there is little doubt that land connection did obtain between Greenland and Europe in Cainozoic times, along this Icelandic ridge, for relics of the same Tertiary flora are found in Scotland, the Færöe Islands, Iceland, and Greenland. The deposits in which these plant-remains occur are associated with great sheets of volcanic rocks, which in the Færöe Islands and Iceland reach a thickness of many thousand feet. Of the same age are the massive basalts of Jan Mayen, Spitzbergen, Franz Joseph Land, and Greenland. These lavas seem seldom to have issued from isolated foci in the manner of modern eruptions, but rather to have welled up along the lines of rectilineal fissures. From the analogy of similar phenomena in other parts of the world it might be inferred that the volcanic action of these northern regions may have been connected with a movement of elevation, and that the Icelandic ridge, if it did not come into existence during the Tertiary period, was at all events greatly upheaved at that time. It would seem most likely, in short, that the volcanic action in question was connected mainly with crustal movements in the oceanic trough. Similar phenomena, as is well known, are met with further south in the trough of the Atlantic. Thus the volcanic Azores rise like Iceland from the surface of a broad ridge which is separated from the continental plateau by wide and deep depressions. And so again, from the back of the great Dolphin Ridge, spring the volcanic islets of St. Paul's, Ascension, and Tristan d'Acunha.

I have treated of the Icelandic bank at some length for the purpose of showing that its volcanic phenomena do not really form an exception to the rule that such eruptions ceased after Palæozoic or early Mesozoic times to disturb the Atlantic coast-lines of Europe and North America. As the bank in question extends between Greenland and the British Islands, it was only natural that both those regions should be affected by its movements. But its history pertains essentially to that of the Atlantic trough; and it seems to show us how transmeridional movements of the crust, accompanied by vast discharges of igneous rock, may come in time to form land connections between what are now widely separated areas.

Let us next turn our attention to the coast-lines of the Gulf of Mexico and the Caribbean Sea. These enclosed seas have frequently been compared to the Mediterranean, and the resemblance is self-evident. Indeed, it is so close that one may say the Mexican-Caribbean Sea and the Mediterranean are rather homologous than simply analogous. The latter, as we have seen, occupies a primitive depression, and formerly covered a much wider area. It extended at one time over much of Southern Europe and Northern Africa, and appears to have had full communica-

tion across Asia Minor with the Indian Ocean, and with the Arctic Ocean athwart the low-lying tracts of North-western Asia. Similarly, it would seem, the Mexican-Caribbean Sea is the remaining portion of an ancient inland sea which formerly stretched north through the heart of North America to the Arctic Ocean. Like its European parallel, it has been diminished by sedimentation and crustal movements. It resembles the latter also in the greatness and irregularity of its depths, and in the evidence which its islands supply of volcanic action as well as of very considerable crustal movements within recent geological times. Along the whole northern borders of the Gulf of Mexico the coast-lands, like those on the Atlantic sea-board of the Southern States, are composed of Tertiary and recent accumulations, and the same is the case with Yucatan; while similar young formations are met with on the borders of the Caribbean Sea and in the Antilles. The Bahamas and the Windward Islands mark out for us the margin of the continental plateau, which here falls away abruptly to profound depths. One feels assured that this portion of the plateau has been ridged up to its present level at no distant geological date. But notwithstanding all the evidence of recent extensive crustal movements in this region, it is obvious that the Mexican-Caribbean depression, however much it may have been subsequently modified, is of primitive origin.[1]

Before we leave the coast-lands of North America I would again point out their leading geological features. In a word, then, they are composed for the most part of Archæan and Palæozoic rocks: no great linear or axial uplifts marked by much flexure of strata have taken place in those regions since Palæozoic times; while igneous action virtually ceased about the close of the Palæozoic or the commencement of the Mesozoic period. It is not before we reach the shores of the Southern States and the coast-lands of the Mexican-Caribbean Sea that we encounter notable accumulations of Mesozoic, Tertiary, and younger age. These occur in approximately horizontal positions round the Gulf of Mexico, but in the Sierra Nevada of Northern Colombia and the Cordilleras of Venezuela Tertiary strata enter into the formation of true mountains of elevation. Thus the Mexican-Caribbean depression, like that of the Mediterranean, is characterised, not only by its irregular depths and its volcanic phenomena, but by the propinquity of recent mountains of upheaval, which bear the same relation to the Caribbean Sea that the mountains of North Africa do to the Mediterranean.

We may now compare the Atlantic coasts of South America with those of Africa. The former coincide in general direction with the edge of the continental plateau, to which they closely approach between Cape St. Roque and Cape Frio. In the north-east, between Cape Paria, opposite Trinidad, and Cape St. Roque, the continental shelf attains a considerably greater breadth, while south of Cape Frio it gradually widens until, in the extreme south, it runs out towards the east in the form of a narrow ridge, upon the top of which rise the Falkland Islands and South Georgia. Excluding from consideration for the present all recent alluvial and Tertiary deposits, we may say that the coast-lands from Venezuela down to the South of Brazil are composed principally of Archæan rocks; the eastern borders of the continent further south being formed of Quaternary and Tertiary accumulations. So far as we know, igneous rocks are of rare occurrence on the Atlantic sea-board. Palæozoic strata approach the coast-lands at various points between the mouths of the Amazons and La Plata, and these, with the underlying and surrounding Archæan rocks, are more or less folded and disturbed, while the younger strata of Mesozoic and Cainozoic age (occupying wide regions in the basin of the Amazons, and here and there fringing the sea-coast), occur in approximately horizontal positions. It would appear, therefore, that no great axial uplifts have taken place in those regions since Palæozoic times. The crustal movements of later ages were regional rather than axial; the younger rocks are not flexed and mashed together, and their elevation (negative or positive) does not seem to have been accompanied by conspicuous volcanic action.

[1] Professor Suess thinks it is probable that the Caribbean Sea and the Mediterranean are portions of one and the same primitive depression which traversed the Atlantic area in early Cretaceous times. He further suggests that it may have been through the gradual widening of this central Mediterranean that the Atlantic in later times came into existence.

The varying width of the continental shelf is due to several causes. The Orinoco, the Amazons, and other rivers descending to the north-east coast, carry enormous quantities of sediment, much of which comes to rest on the submerged slopes of the continental plateau, so that the continental shelf tends to extend seawards. The same process takes place on the south-east coast, where the River Plate discharges its muddy waters. South of latitude 40° S., however, another cause has come into play. From the mouth of the Rio Negro to the terminal point of the continent the whole character of the coast betokens a geologically recent emergence, accompanied and followed by considerable marine erosion. So that in this region the continental shelf increases in width by the retreat of the coast-line, while in the north-east it gains by advancing seawards. It is to be noted, however, that even there, in places where the shores are formed of alluvia, the sea tends to encroach upon the land.

The Atlantic coast of Africa resembles that of South America in certain respects, but it also offers some important contrasts. As the northern coasts of Venezuela and Colombia must be considered in relation rather to the Caribbean depression than to the Atlantic, so the African sea-board between Cape Spartel and Cape Nun pertains structurally to the Mediterranean region. From the southern limits of Morocco to Cape Colony the coastal heights are composed chiefly of Archæan and Palæozoic rocks, the low shore-lands showing here and there strata of Mesozoic and Tertiary age together with still more recent deposits. The existing coast-lines everywhere advance close to the edge of the continental plateau, so that the submarine shelf is relatively narrower than that of Eastern South America. The African coast is still further distinguished from that of South America by the presence of several groups of volcanic islands—Fernando Po and others in the Gulf of Guinea, and Cape Verde and Canary Islands. The last-named group, however, notwithstanding its geographical position, is probably related rather to the Mediterranean depression than to the Atlantic trough.

The geological structure of the African coast-lands shows that the earliest to come into existence were those that extend between Cape Nun and the Cape of Good Hope. The coastal ranges of that section are much denuded, for they are of very great antiquity, having been ridged up in Palæozoic times. The later uplifts (negative or positive) of the same region were not attended by tilting and folding of strata, for the Mesozoic and Tertiary deposits, like those of South America, lie in comparatively horizontal positions. Between Cape Nun and Cape Spartel the rocks of the maritime tracts range in age from Palæozoic to Cainozoic, and have been traced across Morocco into Algeria and Tunis. They all belong to the Mediterranean region, and were deposited at a time when the southern shores of that inland sea extended from a point opposite the Canary Islands along what is now the southern margin of Morocco, Algeria, and Tunis. Towards the close of the Tertiary period the final upheaval of the Atlas took place, and the Mediterranean, retreating northwards, became an almost land-locked sea.

I need hardly stop to point out how the African coast-lines have been modified by marine erosion and the accumulation of sediment upon the continental shelf. The extreme regularity of the coasts is due partly to the fact that the land is nearly coextensive with the continental plateau, but it also results in large measure from the extreme antiquity of the land itself. This has allowed of the cutting-back of headlands and the filling up of bays and inlets, a process which has been going on between Morocco and Cape Colony with probably little interruption for a very prolonged period of time. We may note also the effect of the heavy rains of the equatorial region in washing down detritus to the shores, and in this way protecting the land to some extent from the erosive action of the sea.

What now, let us ask, are the outstanding features of the coast-lines of the Atlantic Ocean? We have seen that along the margins of each of the bordering continents the last series of great mountain-uplifts took place in Palæozoic times. This is true alike for North and South America, for Europe and Africa. Later movements which have added to the extent of land were not marked by the extreme folding of strata which attended the early upheavals. The Mesozoic and Cainozoic rocks, which now and again form the shore-lands, occur in more or less undisturbed

condition. The only great linear uplifts or true mountains of elevation which have come into existence in Western Europe and North Africa since the Palæozoic period trend approximately at right angles to the direction of the Atlantic trough, and are obviously related to the primitive depression of the Mediterranean. The Pyrenees and the Atlas, therefore, although their latest elevation took place in Tertiary times, form no exceptions to the rule that the extreme flexing and folding of strata which is so conspicuous a feature in the geological structure of the Atlantic sea-board dates back to the Palæozoic era. And the same holds true of North and South America. There all the coastal ranges of highly flexed and folded strata are of Palæozoic age. The Cordilleras of Venezuela are no doubt a Tertiary uplift, but they are as obviously related to the Caribbean depression as the Atlas ranges are to that of the Mediterranean. Again, we note that volcanic activity along the borders of the Atlantic was much less pronounced during the Mesozoic period than it appears to have been in earlier ages. Indeed, if we except the great Tertiary basalt-flows of the Icelandic ridge and the Arctic regions, we may say that volcanic action almost ceased after the Palæozoic era to manifest itself upon the Atlantic coast-lands of North America and Europe. But while volcanic action has died out upon the Atlantic margins of both continents, it has continued during a prolonged geological period within the area of the Mediterranean depression. And in like manner the corresponding depression between North and South America has been the scene of volcanic disturbances from Mesozoic down to recent times. Along the African coasts the only displays of recent volcanic action that appertain to the continental margin are those of the Gulf of Guinea and the Cape de Verde Islands. The Canary Islands and Madeira may come under the same category, but, as we have seen, they appear to stand in relationship to the Mediterranean depression and the Tertiary uplift of North Africa. Of Iceland and the Azores I have already spoken, and of Ascension and the other volcanic islets of the South Atlantic it is needless to say that they are related to wrinkles in the trough of the ocean, and therefore have no immediate connection with the continental plateau.

Thus in the geographical development of the Atlantic coast-lines we may note the following stages:—*First*, in Palæozoic times the formation of great mountain-uplifts, frequently accompanied by volcanic action. *Second*, a prolonged stage of comparative coastal tranquillity, during which the maritime ranges referred to were subject to such excessive erosion that they were planed down to low levels, and in certain areas even submerged. *Third*, renewed elevation (negative or positive) whereby considerable portions of the much denuded Archæan and Palæozoic rocks, now largely covered by younger deposits, were converted into high lands. During this stage not much rock-folding took place, nor were any true mountains of elevation formed parallel to the Atlantic margins. It was otherwise, however, in the Mediterranean and Caribbean depressions, where coastal movements resulted in the formation of enormous linear uplifts. Moreover, volcanic action is now and has for a long time been more characteristic of these depressions than of the Atlantic coast-lands.

I must now ask you to take a comprehensive glance at the coast-lines of the Pacific Ocean. In some important respects these offer a striking contrast to those we have been considering. Time will not allow me to enter into detailed description, and I must therefore confine attention to certain salient features. Examining first the shores of the Americas, we find that there are two well-marked regions of fiords and fringing islands—namely, the coasts of Alaska and British Columbia, and of South America from 40° S. lat. to Cape Horn. Although these regions may be now extending seawards in places, it is obvious that they have recently been subject to submergence. When the fiords of Alaska and British Columbia existed as land valleys it is probable that a broad land connection obtained between North America and Asia. The whole Pacific coast is margined by mountain-ranges, which in elevation and boldness far exceed those of the Atlantic sea-board. The rocks entering into their formation range in age from Archæan and Palæozoic down to Cainozoic, and they are almost everywhere highly disturbed and flexed. It is not necessary, even if it were possible, to consider the geological history of all those uplifted masses. It is enough for my

purpose to note the fact that the coastal ranges of North America and the principal chain of the Andes were all elevated in Tertiary times. It may be remarked, further, that from the Mesozoic period down to the present the Pacific borders of America have been the scene of volcanic activity far in excess of what has been experienced on the Atlantic sea-board.

Geographically the Asiatic coasts of the Pacific offer a strong contrast to those of the American borders. The latter, as we have seen, are for the most part not far removed from the edge of the continental plateau. The coasts of the mainland of Asia, on the other hand, retire to a great distance, the true margin of the plateau being marked out by that great chain of islands which extends from Kamchatka south to the Philippines and New Guinea. The seas lying between those islands and the mainland occupy depressions in the continental plateau. Were that plateau to be lifted up for 6,000 or 7,000 feet the seas referred to would be enclosed by continuous land, and all the principal islands of the East Indian Archipelago—Sumatra, Java, Celebes, and New Guinea—would become united to themselves as well as to Australia and New Zealand. In short, it is the relatively depressed condition of the continental plateau along the western borders of the Pacific basin that causes the Asiatic coast-lines to differ so strikingly from those of America.

From a geological point of view the differences are less striking than the resemblances. It is true that we have as yet a very imperfect knowledge of the geological structure of Eastern Asia, but we know enough to justify the conclusion that in its main features that region does not differ essentially from Western North America. During Mesozoic and Cainozoic times the sea appears to have overflowed vast tracts of Manchooria and China, and even to have penetrated into what is now the great Desert of Gobi. Subsequent crustal movements revolutionised the geography of all those regions. Great ranges of linear uplifts came into existence, and in these the younger formations, together with the foundations on which they rested, were squeezed into folds and ridged up against the nuclei of Palæozoic and Archæan rocks which had hitherto formed the only dry land. The latest of these grand upheavals are of Tertiary age, and, like those of the Pacific slope of America, they were accompanied by excessive volcanic action. The long chains of islands that flank the shores of Asia we must look upon as a series of partially submerged or partially emerged mountain-ranges, analogous geographically to the coast ranges of North and Central America, and to the youngest Cordilleras of South America. The presence of numerous active and recently extinct volcanoes, taken in connection with the occurrence of many great depressions which furrow the floor of the sea in the East Indian Archipelago, and the profound depths attained by the Pacific trough along the borders of Japan and the Kurile and Aleutian Islands—all indicate conditions of very considerable instability of the lithosphere. We are not surprised, therefore, to meet with much apparently conflicting evidence of elevation and depression in the coast-lands of Eastern Asia, where in some places the sea would seem to be encroaching, while in other regions it is retreating. In all earthquake-ridden and volcanic areas such irregular coastal changes may be looked for. So extreme are the irregularities of the sea-floor in the area lying between Australia, the Solomon Islands, the New Hebrides, and New Zealand, and so great are the depths attained by many of the depressions, that the margins of the continental plateau are harder to trace here than anywhere else in the world. The bottom of the oceanic trough throughout a large portion of the Southern and Western Pacific is, in fact, traversed by many great mountain ridges, the summits of which approach the surface again and again to form the numerous islets of Polynesia. But notwithstanding the considerable depths that separate Australia from New Zealand there is geological evidence to show that a land connection formerly linked both to Asia. The continental plateau, therefore, must be held to include New Caledonia and New Zealand. Hence the volcanic islets of the Solomon and New Hebrides groups are related to Australia in the same way as the Liu-kiu, Japanese, and Kurile Islands are to Asia.

Having rapidly sketched the more prominent features of the Pacific coast-lines, we are in a position to realise the remarkable contrast they present to the coast-

lines of the Atlantic. The highly folded strata of the Atlantic sea-board are the relics of great mountains of upheaval, the origin of which cannot be assigned to a more recent date than Palæozoic times. During subsequent crustal movements no mountains of corrugated strata were uplifted along the Atlantic margins, the Mesozoic and Cainozoic strata of the coastal regions showing little or no disturbance. It is quite in keeping with all this that volcanic action appears to have been most strongly manifested in Palæozoic times. So many long ages have passed since the upheaval of the Archæan and Palæozoic mountains of the Atlantic sea-board that these heights have everywhere lost the character of true mountains of elevation. Planed down to low levels, partially submerged and covered to some extent by newer formations, they have in many places been again converted into dry lands, forming plateaus—now sorely denuded and cut up into mountains and valleys of erosion. Why the later movements along the borders of the Atlantic basin should not have resulted in the wholesale plication of the younger sedimentary rocks is a question for geologists. It would seem as if the Atlantic margins had reached a stage of comparative stability long before the grand Tertiary uplifts of the Pacific borders had taken place; for, as we have seen, the Mesozoic and Cainozoic strata of the Atlantic coast-lands show little or no trace of having been subjected to tangential thrusting and crushing. Hence one cannot help suspecting that the retreat of the sea during Mesozoic and Cainozoic ages may have been due rather to subsidence of the oceanic trough and to sedimentation within the continental area than to positive elevation of the land.

Over the Pacific trough, likewise, depression has probably been in progress more or less continuously since Palæozoic times, and this movement alone must have tended to withdraw the sea from the surface of the continental plateau in Asia and America. But by far the most important coastal changes in those regions have been brought about by the crumpling up of the plateau, and the formation of gigantic mountains of upheaval along its margins. From remotest geological periods down almost to the present the land area has been increased from time to time by the doubling-up and consequent elevation of coastal accumulations and by the eruption of vast masses of volcanic materials. It is this long-continued activity of the plutonic forces within the Pacific area which has caused the coast-lands of that basin to contrast so strongly with those of the Atlantic. The latter are incomparably older than the former, the heights of the Atlantic borders being mountains of denudation of vast geological antiquity, while the coastal ranges of the Pacific slope are creations but of yesterday as it were. It may well be that those Cordilleras and mountain-chains reach a greater height than was ever attained by any Palæozoic uplifts of the Atlantic borders. But the marked disparity in elevation between the coast-lands of the Pacific and the Atlantic is due chiefly to a profound difference in age. Had the Pacific coast-lands existed for as long a period and suffered as much erosion as the ancient rocks of the Atlantic sea-board, they would now have little elevation to boast of.

The coast-lines of the Indian Ocean are not, upon the whole, far removed from the margin of the continental plateau. The elevation of East Africa for 6,000 feet would add only a very narrow belt to the land. This would still leave Madagascar an island, but there are geological reasons for concluding that this island was at a far distant period united to Africa, and it must therefore be considered as forming a portion of the continental plateau. The great depths which now separate it from the mainland are probably due to local subsidence, connected with volcanic action in Madagascar itself and in the Comoro Islands. The southern coasts of Asia, like those of East Africa, approach the edge of the continental plateau, so that an elevation of 6,000 feet would make little addition to the land area. With the same amount of upheaval, however, the Malay Peninsula, Sumatra, Java, and West Australia would become united, but without extending much further seawards. Land connection, as we know, existed in Mesozoic times between Asia, Australia, and New Zealand, but the coast-lines of that distant period must have differed considerably from those that would appear were the regions in question to experience now a general elevation. The Archæan and Palæozoic rocks of the Malay Peninsula and Sumatra are flanked on the side of the Indian Ocean by great

volcanic ridges, and by uplifts of Tertiary strata, which continue along the line of the Nicobar and Andaman Islands into Burma. Thus the coast-lines of that section of the Indian Ocean exhibit a geographical development similar to that of the Pacific sea-board. Elsewhere, as in Hindustan, Arabia, and East Africa, the coast-lines appear to have been determined chiefly by regional elevations of the land or subsidence of the oceanic trough in Mesozoic and Cainozoic times, accompanied by the outwelling of enormous floods of lava. Seeing, then, that the Pacific and the Indian Oceans are pre-eminently regions which, down to a recent date, have been subject to great crustal movements and to excessive volcanic action, we may infer that in the development of their coast-lines the sea has played a very subordinate part. The shores, indeed, are largely protected from marine erosion by partially emerged volcanic ridges and by coral islands and reefs, and to a considerable extent also by the sediment which in tropical regions especially is swept down to the coast in great abundance by rains and rivers. Moreover, as the geological structure of these regions assures us, the land would appear seldom to have remained sufficiently long at one level to permit of much destruction by waves and tidal currents.

In fine, then, we arrive at the general conclusion that the coast-lines of the globe are of very unequal age. Those of the Atlantic were determined as far back as Palæozoic times by great mountain uplifts along the margin of the continental plateau. Since the close of that period many crustal oscillations have taken place, but no grand mountain-ranges have again been ridged up on the Atlantic sea-board. Meanwhile the Palæozoic mountain-chains, as we have seen, have suffered extensive denudation, have been planed down to the sea-level, and even submerged. Subsequently converted into land, wholly or partially as the case may have been, they now present the appearance of plains and plateaus of erosion, often deeply indented by the sea. No true mountains of elevation are met with anywhere in the coast-lands of the Atlantic, while volcanic action has well-nigh ceased. In short, the Atlantic margins have reached a stage of comparative stability. The trough itself, however, is traversed by at least two well-marked banks of upheaval —the great meridional Dolphin Ridge, and the approximately transmeridional Færöe-Icelandic belt—both of them bearing volcanic islands.

But while the coast-lands of the Atlantic proper attained relative stability at an early period, those of the Mediterranean and Caribbean depressions have up to recent times been the scenes of great crustal disturbance. Gigantic mountain-chains were uplifted along their margins at so late a period as the Tertiary, and their shores still witness volcanic activity.

It is upon the margins and within the trough of the Pacific Ocean, however, that subterranean action is now most remarkably developed. The coast-lines of that great basin are everywhere formed of grand uplifts and volcanic ranges, which, broadly speaking, are comparable in age to those of the Mediterranean and Caribbean depressions. Along the north-east margin of the Indian Ocean the coast-lines resemble those of the Pacific, being of like recent age, and similarly marked by the presence of numerous volcanoes. The northern and western shores, however (as in Hindustan, Arabia, and East Africa), have been determined rather by regional elevation or by subsidence of the ocean-floor than by axial uplifts, the chief crustal disturbances dating back to an earlier period than those of the East Indian Archipelago. It is in keeping with this greater age of the western and northern coast-lands of the Indian Ocean that volcanic action is now less strongly manifested in their vicinity.

I have spoken of the comparative stability of the earth's crust within the Atlantic area as being evidenced by the greater age of its coastal ranges and the declining importance of its volcanic phenomena. This relative stability is further shown by the fact that the Atlantic sea-board is not much disturbed by earthquakes. This, of course, is what might have been expected, for earthquakes are most characteristic of volcanic regions and of those areas in which mountain-uplifts of recent geological age occur. Hence the coast-lands of the Pacific and the East Indies, the borders of the Caribbean Sea, the volcanic ridges of the Atlantic basin, the lands of the Mediterranean, the Black Sea, and the Aralo-Caspian depressions,

the shores of the Red Sea, and vast tracts of Southern Asia, are the chief earthquake regions of the globe. It may be noted, further, that shocks are not only most frequent but most intense in the neighbourhood of the sea. They appear to originate sometimes in the volcanic ridges and coastal ranges, sometimes under the floor of the sea itself. Now earthquakes, volcanoes, and uplifts are all expressions of the one great fundamental fact that the earth is a cooling and contracting body, and they indicate the lines of weakness along which the enormous pressures and strains induced by the subsidence of the crust upon its nucleus find relief. We cannot tell why the coast-lands of the Atlantic should have attained at so early a period a stage of relative stability—why no axial uplifts should have been developed along their margins since Palæozoic times. It may be that relief has been found in the wrinkling-up of the floor of the oceanic trough, and consequent formation of the Dolphin Ridge and other great submarine foldings of the crust; and it is possible that the growth of similar great ridges and wrinkles upon the bed of the Pacific may in like manner relieve the coast-lands of that vast ocean, and prevent the formation of younger uplifts along their borders.

I have already remarked that two kinds of elevatory movements of the crust are recognised by geologists—namely, axial and regional uplifts. Some, however, are beginning to doubt, with Professor Suess, whether any vast regional uplifts are possible. Yet the view that would attribute all such apparent elevations of the land to subsidence of the crust under the great oceanic troughs is not without its difficulties. Former sea-margins of very recent geological age occur in all latitudes, and if we are to explain these by sub-oceanic depression, this will compel us to admit, as Suess has remarked, a general lowering of the sea-level of upwards of 1,000 feet. But it is difficult to believe that the sea-floor could have subsided to such an extent in recent times. Suess thinks it is much more probable that the high-level beaches of tropical regions are not contemporaneous with those of higher latitudes, and that the phenomena are best explained by his hypothesis of a secular movement of the ocean—the water being, as he contends, alternately heaped up at the equator and the poles. The strand-lines in high latitudes, however, are certainly connected with glaciation in some way not yet understood; and if it cannot be confidently affirmed that they indicate regional movements of the land, the evidence, nevertheless, seems to point in that direction.

In concluding this imperfect outline-sketch of a large subject, I ought perhaps to apologise for having trespassed so much upon the domains of geology. But in doing so I have only followed the example of geologists themselves, whose divagations in territories adjoining their own are naturally not infrequent. From much that I have said, it will be gathered that with regard to the causes of many coastal changes we are still groping in the dark. It seems not unlikely, however, that as light increases we may be compelled to modify the view that all oscillations of the sea-level are due to movements of the lithosphere alone. That is a very heretical suggestion; but that a great deal can be said for it anyone will admit after a candid perusal of Suess's monumental work, 'Das Antlitz der Erde.'

The following Papers were read:—

1. *First Ascent of the Oraefa Jökull, Iceland.* *By* F. W. W. Howell.

[Will be published in the 'Proceedings of the R.G.S.']

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2. *Place-names.* *By* Dr. J. Burgess.

Dr. Burgess, like most Oriental scholars, took exception to the phonetic principle in rendering the place-names of countries which have a native literature. It was more scholarly and more satisfactory, he maintained, to adopt a definite transliteration of each foreign alphabet, based, of course, on the best authorised form of the name in each instance. Dealing more particularly with the question of Scottish place-names, he referred at some length to the errors in Gaelic spelling found on

some sheets of the Ordnance Survey maps. The unsatisfactory rendering of these names induced Sir Charles Wilson some time ago to suggest the revision of the nomenclature of the Highland sheets by a Committee of the Royal Scottish Geographical Society, and of this committee Dr. Burgess has acted as convener.

[A committee of the Association was subsequently appointed to report on Scottish place-names, with a small grant.]

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3. *Rainfall in Formosa and some of the Effects on the Island and Mainland of China.* By J. Thomson.

The following notes on the rainfall of Formosa are the result partly of personal observation while exploring the south of the island, and partly of meteorological and such other statistics as I have been able to consult.

The island affords a striking example of the work of rain within a contracted area in altering the surface of the land, building up plains seawards, and ultimately fitting them for tillage and the support of an increasing population.

It will be necessary to note the geographical position and configuration of the island, ocean currents, temperature, and prevailing winds, in order to make the subject intelligible.

Formosa lies between 21° and 25° north latitude, while the 121st degree of east longitude divides it into nearly equal parts from north to south. It is over 200 miles long, and its width varies from fifty to eighty miles. It is traversed by a spine of lofty mountains throughout its whole length from north to south, having a maximum altitude of 12,000 feet.

It will be seen that after the rains the drainage of this chain is necessarily carried over a very small area, and that the changes caused by erosion and the deposit of detritus must be well defined. The Pacific Gulf Stream, known to the Japanese as 'Korosiwo,' flows north on the eastern side, raising the mean temperature of Formosa to about ten degrees higher than that of the mainland. The prevailing winds throughout the year are the north-east and south-west monsoons. The former begins to blow about the end of October and continues on to April.

In its passage across the ocean from the north it is charged with moisture taken up from the warm Gulf Stream, and coming in contact with the lofty mountain barrier of Formosa, it is forced up to a great altitude, where its burden of vapour is liberated by the lighter and colder air. This is discharged over the forest-clad heights in copious rain.

On the eastern side the rain descends through chasms and gorges in torrential streams, and cataracts carry it back to the ocean. The eastern side presents a rocky front to the sea. The denudation of the mountains by erosion and its effects can hardly be traced on this side of the island, as the detritus is deposited in the deep sea adjoining the cliffs. On the west of the central chain, where the gradient is more gentle, we find an extensive plain, part of which has been built up within the historic era by the detritus washed down from the mountains, and the major part in a similar manner during the Carboniferous period, as may be gathered from extensive coral islands (and other geological formations) which now form part of the low-lying land redeemed from the bed of the ocean.

But we need go no further back for evidence of the rapid upbudding of the western plain than the date of the Dutch occupation in 1634.

Two forts were erected—one, Providentia, at the mouth of the Formosa River (Taiwanfu), the other on the island of Taiwan. The former may now be traced within the walls of Taiwanfu, more than five miles inland over the plain, while Taiwan with its fort has been long united to the mainland.

Evidence of how this change has been accomplished exists in the table-lands and spurs of the central range, about fifteen miles inland from Taiwanfu, in the manner in which these lower 'no man's lands,' so named by the Chinese, are cut up and demolished by the drainage of the lofty chain, chasms cut out by torrents during the rainy season, vast funnel-shaped pits where the land has fallen in undermined by water, broad river beds cut deep into the table-lands, their banks

strewn with rounded and polished boulders of gigantic proportions that have been driven from inaccessible heights and rounded on their downward course to the plain. The greater part of the plain is 'an alluvium,' a rich loam derived partly from the shales of the central mountains, partly from the sandstones south, and partly from the limestone hills which reach here and there above the level of the lowland. These are the great and small Kangshan, the white bank, Apeshill, Saracenshead, Fingshan; also still more elevated hills inland approaching Baksa Valley; by water, Lambay island near Tangkang. We see thus within the narrow compass of the island of Formosa rainfall and its results, year by year adding to the habitable plain, and creating extensive shoals between the island and mainland.

Another phase of rain-work in Formosa is the effect which the central mountain range has in withdrawing the moisture from the atmosphere as it sweeps over the island during the north-east monsoon, and conferring on the mainland of Fakim Kwangtung, a province of China, one of the finest winter climates in the world.

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4. *On the Windings of Rivers.* *By* J. Y. Buchanan, *F.R.S.*

This paper summarised the hydrokinetical principles which regulate the form and size of the curves traced out by rivers in their windings, forms which are largely independent of the character of the ground.

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5. *Travels in Lesser Thibet.*[1] *By* Mrs. Bishop.

FRIDAY, AUGUST 5.

The following Papers were read:—

1. *On Meteorological Observations in the Atlantic Ocean.* *By the* Prince of Monaco.

The western shores of Europe, especially those of Great Britain and Ireland, are exposed to continual devastations by storms which come from the westward. The only source from which we can obtain warning is the continent of North America, and the warnings thence received are of the greatest value. But the width of the North Atlantic is so great that American storms lose themselves, and others are generated of which Europeans can at present receive no warning. The North Atlantic is fairly rich in islands, and in nearly every group there is at least one island of remarkable altitude, where the meteorological conditions are likely to be quite distinct from those obtaining at the sea-level. The results already achieved at the high-level observatory on Ben Nevis justify the confident expectations that equally and perhaps more valuable results would be obtained by the establishment of a pair of high- and low-level observatories in one of the Atlantic groups of islands, preferably the Azores. These groups of islands either are already, or will be shortly, connected by cable with Europe, and the author strongly advocates that we should now establish meteorological observing stations at carefully selected sea-level places having cable connection with Europe, and at least one high-level observatory at the top of one of the remarkable peaks suggested. Further, as it might be advantageous to have these observations collected at an observatory where much attention is given to oceanographical work, he offers to undertake at Monaco the collection and discussion of the observations received daily, and the distribution of the results.

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[1] Published in the *Scottish Geographical Magazine.*

2. *The Density, Temperature, and Motion of the Waters of the Gulf of Guinea.* *By* J. Y. Buchanan, *F.R.S.*

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3. *Physical Geography of the Firth of Forth.* *By* Hugh Robert Mill, *D.Sc.*, *F.R.S.E.*

The configuration of the Firths of Forth and Tay and of the neighbouring parts of the North Sea was briefly described, references being given to previous papers bearing on the physical conditions of the water.[1] Since the publication of these papers the results of the observations at fixed stations by the Fishery Board for Scotland furnish data for a more complete discussion. The new information mainly concerns the rate of increase of transparency in the water from the river seaward and the effects of tidal action on temperature and salinity. The configuration of the coast and the set of the tides, together with the relative strength of current at springs and neaps, and the hour at which these extreme tides occur, explain many apparent anomalies in seasonal change of temperature. In summer estuary water is warmer, in winter colder, than that of the sea; so that, disregarding solar influence, the temperature of the water at a station near the mouth of an estuary is either at a maximum or a minimum at high-water and low-water, the maximum occurring with low-water in summer, with high-water in winter. Apart from this, there is a diurnal range of temperature due to solar heating and cooling by radiation, which in the absence of tides would produce a maximum in the afternoon and a minimum in the early morning. Spring tides recur fortnightly at the same hour, and evince the special tidal characteristics in an extreme degree. It so happens that on the east coast of Scotland low-water springs occur in the morning and high-water in the afternoon, and the observations at 9.0h. and 15.0h. accordingly show the resultants of this effect at the maximum. In summer, when low water occurs in the afternoon, the afternoon temperature at the Abertay lightship is over 1° C. higher than in the morning, and when high-water occurs in the afternoon the temperature is nearly 1° C. lower than in the morning, no matter how strong the solar heating may be.

[These papers have been published in the 'Proceedings of the R.G.S.,' Sept. 1892, p. 622.]

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4. *On the Need for Teaching in Meteorology.* *By* H. N. Dickson, *F.R.S.E.*, *F.R.Met.Soc.*

The selection of subjects for elementary scientific instruction raises several questions concerning the relations of the different branches of physical science to each other. Apart from special applications to arts and manufactures, a want is felt of a subject which shall at the same time afford opportunities of illustrating scientific methods and give examples of practical value in accounting for many natural phenomena of common observation. The ordinary phenomena of meteorology, as embodied in the weather folk-lore current everywhere, are already familiar to sailors, fishermen, and farmers, the classes it is most important to reach, and by properly classifying and arranging the facts already known to them several laws may be made to suggest themselves. In this way the meteorological elements, which in this restricted sense underlie a great part of biology, geology, and geography, form an introduction to the fundamental notions of these sciences, as well as to those of physics involved in their discussion.

There is as yet no instruction in meteorology available anywhere in this country, but in view of the rapid development of technical education it is urgent that this should be remedied.

The best method of properly introducing the subject seems to be that the facts of the case should be set before the Technical Education Committees of the County

[1] See 'River Entrances,' in *Supp. Papers, Roy. Geog. Soc.*; and *Report of the Fishery Board for Scotland*, 1891, pp. 353-387.

Councils, backed by the approval of the various bodies whose function it is to regulate and extend scientific instruction. In this way a demand for teaching in meteorology would be created, and the supply should come from some of the main fixed centres of technical education, which should not only supply systematic instruction, but should be in a position to deal with questions referring to the relations of meteorology to agriculture, fisheries, &c., and to discuss the data collected by the teachers sent out bearing on local observations and prognostics.

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5. *The Desert of Atacama.* *By* Mrs. Lillie Grove.

The desert of Atacama spreads over two Chilian provinces, Atacama and Antofagasta. It lies between the Pacific and the Andes, and between the rivers Loa and Copiapo to the north and south. It rises gradually to the Cordillera real, forming a kind of amphitheatre, in the midst of which are arid plains and vast salt lakes. One of the latter, Lake Askotan, is quite dried up, and its bed of salt is dotted with a few islands and tepid water puddles called 'water-eyes.' It is surrounded by high mountains, many of which are volcanic. Above this amphitheatre is the tableland of the Andes, 13,000 feet high, called *Puna*, which word is the origin of the name given to mountain-sickness.

Turning to the industrial history of the desert, we find that it was a terror to all except the conquering Spaniards until the end of the last century; and while the silver mines of Potosi were being successfully worked the treasures of this region lay unexplored. In 1832 Juan Yodoi, a shepherd, found the silver mine of Chanarcillo, and then a legion of courageous and hardy cateadores (mine-seekers) laid siege, as it were, to the mountains. The discoveries of silver and copper mines, of beds of guano, of nitrates, and borate of lime followed one another in quick succession, and laid the foundation of great commercial prosperity. The Government gave its countenance and help to the work, sending out scientific commissioners and giving security to capitalists.

The great work which requires special notice is the railway from Antofagasta to Uyuni, which is a marvel of engineering skill. It scales a plateau 13,000 feet high and winds through a desert plain. The whole journey lasts three days, and is not entirely a pleasant experience, as the sun, falling on the white soil, makes a blinding glare, and the heat and thirst are almost unbearable. On the way that strange phenomenon of the desert, the mirage, was seen by the traveller. The plain, which stretches out to the horizon, was dotted over with the graves of the victims of the desert. It is interesting to notice that the soil and the air are such that bodies do not decay in the ground, and the inhabitants are in the habit of removing the corpses of their friends from place to place. At night the cold is intense, the changes of temperature being a great hardship. As the line rises the prospect becomes more varied: the road winds round the Limon Verde, and below is the basin of Atacama in the midst of the desert, while all around are the mighty volcanoes, Licancour, San Pedro, and others. Then the line descends into the valley of the Loa. Halt for the night is made at Calama, 'The Queen of the Desert,' where the hotel is comfortable on the whole. The journey is continued on the next day past Askotan, on the edge of the lake, and Cebollar, where there are mines of ice. From Calama another hardship is added to the heat, namely, mountain-sickness, which affects nearly everyone. It is caused partly by the pressure of the atmosphere, partly by the dryness of the air, which cuts the face mercilessly. Ollague is the stopping-place for the second night, and the next evening the arduous journey is completed, and the terminus Uyuni is reached. Here the Bolivian Government intends to build a town, which will be the centre of silver mining in South America.

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6. *Photography as a Means of Surveying.* *By* Colonel H. C. O. Tanner.

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7. *Some Notes on a New Method for the Determination of Geographical Longitudes by Lunar Distances.* *By* Dr. H. Schlichter.

Lunar distances as a means for the strictly accurate determination of geographical longitudes have been little used of late, partly on account of the splendid chronometers with which ships are now provided, and partly owing to the inaccuracies of the instruments commonly employed for lunars. For exploring expeditions on land, however, chronometers are of little value, and the other astronomical phenomena which may be used besides lunar distances are either too difficult of accurate observation by the majority of travellers, or occur too seldom, or are not accurate enough.

The author therefore introduces a new method of observation and measurement of lunar distances, viz., by obtaining a parallel series of photographs of the moon and a fixed star or planet on one plate, and afterwards measuring the distances on the plate. For the elimination of all possible inaccuracies of the photographic film or of the lens, the lunar distances thus registered are checked by repeatedly photographing on the same plate two fixed stars, the positions of which are given in the 'Nautical Almanac,' and the angular distance of which can easily be computed therefrom. The angular distances of the photographic lunars are then found by a simple proportion. The time for taking a set of eight photographic lunars on one plate does not exceed three to four minutes, and micrometric measurements show with perfect accuracy the change of the lunar distances (owing to the movement of the moon) during each interval of the eight observations. The minute accuracy of the method is hereby established. The micrometric measurements on the plate are made by means of the same '*réseau*' which is employed by the principal observatories for stellar photography, and the measurements may therefore be regarded as absolutely correct. Results thus obtained give the correct longitude of the place of observation.

The author proposes to use this method for scientific expeditions into the interior of continents, &c., as well as for the further determination and correction of secondary meridians in navigation. For both purposes it is especially adapted on account of its minute accuracy and great simplicity.

[The paper will be published in the 'Proceedings of the R.G.S.']

SATURDAY, AUGUST 6.

The Section did not meet.

MONDAY, AUGUST 8.

The following Papers and Reports were read:—

1. *Notes on a Portion of the Kalahari.* *By* E. Wilkinson.

These notes, which are accompanied by a map, deal with that portion of the Kalahari lying north of a line between Kuis and Honing Vley. The author is inclined to doubt the accuracy of the position of Kuis as given in previous maps, and the location, if not the existence, of the fork of the Molopo River which is represented in them. The soil of the district appears to be a heavy loose sand, which supports, nevertheless, an abundance of coarse grass, and is densely studded, rather than covered, with low timber and bush. In the few places where water is obtainable, the cattle look well, but the scarcity of water is the curse of the district, and the natives say that it will pass the wit even of white men to find it there. A great portion of the notes is taken up with this question of water

supply, and they contain valuable extracts from a report by Mr. Penning, F.G.S., on that subject. If, as Mr. Penning believes, water in sufficient quantities could be obtained by boring, the author thinks that the country might have a future in the hands of a powerful company which could afford to open up waters and use the district as a vast cattle range, but he evidently does not think it can ever be a country for farms of an ordinary size, or for agriculture in any way.

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2. *The Geography of the Zimbabwe Ruins in Mashonaland.* *By* J. Theodore Bent.

The author began with a few remarks on the nature of the ruins, their position and extent, the vast gold industry anciently carried on in their vicinity, and the probable line of approach to them. He then dealt with the early authorities on the geography of the east coast of Africa: the Periplus, Ptolemy, Eratosthenes, and the vague remarks of Herodotus. The position of Rhapta, Prasum, and other points on this coast was discussed. The expedition to the land of Punt in the reign of Queen Hatusou, and the treasures brought back thence, and the mythical expeditions related by Greeks of voyages in search of gold were then dealt with, as also the Biblical and classical evidence concerning the voyages of the Phœnicians and Arabians in search of gold, and the wealth of Southern Arabia in the precious metal. The author then dealt with early Arabian evidence as to the condition of Mashonaland in the centuries immediately after the introduction of Mohammedanism, Arab travellers A.D. 851, and the evidence given us on this subject by El Masoudi, Zaneddin, and others. The value of the Portuguese evidence on this subject was thoroughly discussed from travellers and writers of the fifteenth and sixteenth centuries. The author concluded by referring to the rediscovery of the ruins by Karl Mauch, and the evidence of the finds in the recent excavations.

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3. *Report of the Mashonaland Committee.*—See Reports, p. 538.

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4. *The Orientation and Architectural Features of the Ruined Temples of Mashonaland.* *By* Robert M. W. Swan.

The temples in Mashonaland seem all to have been oriented to either the rising or the setting sun at one of the solstices, and in all the less ruinous temples very obvious evidence remains of such orientation in the decoration on the exterior of the walls of these temples. This decoration on the great temple consists of a double band of a chevron pattern, and it extends along the part of wall which is directly opposed to the rays of the rising sun at the midsummer solstice.

Means were provided for marking the time of the occurrence of the solstice, and in the interior of the great temple there is a high monolith which would receive the shadow of another monolith placed on the wall at the middle of the decoration when the sun rose at the midsummer solstice.

The great temple at the first glance seems to be roughly elliptical in form, but when carefully measured its walls are found to be built on a number of circular curves of different radii, and the principle governing the length of these radii is interesting. The great tower has a diameter at its base of 17·17 feet (= 10 cubits of 20·62 inches), and this length multiplied by the ratio of circumference to diameter (3·14) or by the square of this ratio gives either the radius or the diameter, or half or double of these, of the curves of all the walls of the best period which we have measured in Mashonaland.

Altars were sometimes erected at the centres of these curves, and means were provided for observing from these altars the culminations of stars of the northern hemisphere.

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5. *The Industrial Geography of Nyassaland.* *By* J. Y. Buchanan, *F.R.S.*

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6. *Across the Veldt to Lobengula's Capital.* *By* Lieut. H. Crichton Browne.

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7. *On Opening Relations with the Hausa Race of West Soudan.* *By* A. Herbert Hallen.

I. In the Western Soudan there are many tribes, but two chief—Hausa and Fellani. Fellani or Fulbe: these are warlike, fanatical, pastoral. The Hausa are brave, but not so fond of war; not fanatical, but commercial. Where the two come in contact Hausa language predominates.

II. The author gave a sketch outline of Hausa land, its population, physical geography, meteorology and climate, political economy, nature of people and social economy, slavery, education, towns, religion.

III. The author then spoke of the work to be done and of the necessity of learning the Hausa language. He pointed out (1) the commercial importance; (2) previous work and its shortcomings in this direction; (3) comparative philology; (4) dialects; (5) writing in Arabic characters. He then went on to refer to ethnology, customs, history, folk-lore, music, climatology, geology, &c. Mr. Hallen then described his proposed method of work under the heads:—(*a*) Preliminary knowledge of Arabic; (*b*) preliminary residence in Tripoli; (*c*) residence in Hausa—where? and methods of drawing the people: (1) personal influence and discussion; (2) medical; (3) non-interference in local politics; (4) educational, (i.) juvenile, (ii.) adult; (5) diffusion of useful books, specially simple illustrated agricultural books, in their own language.

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8. *Report of the Committee on the Climatological and Hydrographical Conditions of Tropical Africa.*—See Reports, p. 367.

TUESDAY, AUGUST 9.

The following Papers were read:—

1. *On Professor Albrecht Penck's Proposed Map of the World on a Scale of 1 : 1,000,000.* *By* E. G. Ravenstein.

At the recent Geographical Congress of Bern Dr. Penck proposed the publication of a map of the entire world on a uniform scale of 1 : 1,000,000. This proposition was favourably entertained, and a committee was appointed to take steps for its realisation. That the scale chosen is the most suitable for the purpose will hardly be doubted by anyone practically acquainted with the mapping of the world. To construct such a map on a projection embracing considerable portions of the earth's surface, if not entire continents, would necessarily have led to an amount of distortion quite inadmissible in a map on such a scale. Dr. Penck, therefore, does wisely to accept the method of drawing each sheet on an independent projection, which was first adopted in India, and has subsequently been introduced into Germany, Austria, the United States, and other countries. By this method the separate sheets are nearly equivalent and orthomorphic, the error for a 5-degree sheet under low latitudes, never exceeding 4 1-1050ths. This is less than the error due to the expansion of the paper in the printing-press. Each sheet, up to 60° N., would embrace five degrees in each direction; the more northern sheets would embrace ten degrees of longitude each. The representation of the whole earth, including the sea, would require 936 of these sheets, whilst the land alone could be shown on 769 sheets.

Physical and political features are to be adequately considered. Rivers are to

be in blue, hills in brown. Contours are to be drawn at 100, 300, 500, and 1,200 metres, and the areas enclosed by them, which Dr. Penck assumes to be equivalent, are to be tinted. Those sheets which deal with countries already surveyed would be engraved in copper; the remaining sheets might be lithographed.

The Greenwich meridian is proposed for acceptance, but all altitudes are to be in metres. The official spelling of all countries using the Latin alphabet is to be retained, even in their 'spheres of influence.' Other alphabets are to be transliterated in accordance with a system to be agreed upon, whilst names in unwritten languages would be spelt phonetically.

Dr. Penck estimates the cost of an edition of 1,000 copies of this map (land surface only) at 191,438*l.*, and as the sale of this edition at 2*s.* a sheet would produce only 88,000*l.*, the deficit of 103,438*l.* would have to be made up by the Governments concerned or by liberal private patrons.

There is nothing Utopian about the scheme, as far as I can see. Difficulties may arise as to the spelling of the names or the introduction of the metre, but the essential thing, to my mind, is the production of a map—a map on an uniform scale. If it is borne in mind that twenty-five 5-degree sheets of such a map of Africa were, some years ago, published by me, with the help of the Royal Geographical Society, and that twenty-one sheets of the same map are now in course of preparation, and that all this was done by me unaided, it must be admitted that better and speedier results might be brought about by an organised co-operation.

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2. *A Recent Journey in Yemen.* *By* WALTER B. HARRIS.

Mr. Walter B. Harris' paper on Yemen deals with a journey undertaken by him in the early months of this year, and during the rebellion of the Arabs against the Turks. Mr. Harris started from Aden early in January without guards, and accompanied only by one of his trusted Morocco servants and a guide, all three mounted on camels. Passing through Lahej, Mr. Harris continued his journey over the desert until, after issuing from the mountain gorges of Khoreiba, he reached Kataba, the Turkish frontier town, and by means of a disguise succeeded in obtaining a permit to pass into Turkish territory. From Kataba to Yerim the journey was a very dangerous one, and the travelling was nearly all accomplished by night, the day being spent in hiding in the jungle. From Yerim the journey was continued to Dhamar, and thus to Sanaa, the capital; Mr. Harris having taken nineteen days in accomplishing the distance, nearly three hundred miles.

On his arrival at Sanaa he was seized by the Turkish authorities and thrown into prison, where, owing to the unhealthy state of the place and the bad water supplied to him, he was taken ill with fever. On the fifth day of his imprisonment he was sent away to Hodaidah on the Red Sea coast under an escort of Turkish soldiers, the journey occupying about five days, the distance being something under two hundred miles. Mr. Harris passed through much wonderfully beautiful scenery, and has brought back an account of Arabia Felix which entirely belies one's ideas of that country. By most people Arabia is considered to be a desert, but Mr. Harris has found that Yemen at least is a country of magnificent fertility, the great plateau, lying at an elevation of from seven to nine thousand feet above the sea level, being in a state of excellent cultivation. Water is by no means scarce; in fact in many places there are rivers of no inconsiderable size. Although the journey has been made once or twice before, Mr. Harris is probably the first European who has reached Sanaa from Aden. After much hard travelling, several narrow escapes, four days' imprisonment in a Turkish gaol, and a violent attack of fever, Mr. Harris reached Aden towards the end of February with a considerable number of photographs and a large collection of notes and sketches pertaining to a country of which but very little is known. An account of the rebellion was written by him to the 'Times,' and published on April 23. At any time the journey would not be an easy one, and, considering that the country was in a state of revolt, Mr. Harris had to overcome very many difficulties before reaching Sanaa.

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3. *A Recent Visit to the Chatham Islands, and some Points in Connection with Geographical Distribution.* *By* H. O. Forbes, *F.Z.S.*

[Will be published in the 'Proceedings of the R.G.S.']

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4. *On some Recent Explorations in British New Guinea.* *By* Coutts Trotter.

The writer described the bearing of some recent journeys on the physical geography of New Guinea, but dwelt with especial emphasis on the marvellous development among the natives, within the last two or three years, of confidence and friendship, and of a comprehension of the principles of law and order—due to the enlightened administration of the Governor, Sir William Macgregor.

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5. *The Eastern Laos States of Siam in the Mêkong Valley.*[1] *By* W. R. D. Beckett, *of H.M.'s Consular Service in Siam.*

This paper is briefly descriptive of a journey taken by Mr. W. R. D. Beckett, under instructions from H.B.M.'s Minister at Bangkok, through the Eastern Laos States of Siam, and extending over a period dating from November 25, 1891, to April 4, 1892. Mr. Beckett's first objective point was the town of Korat, the capital and the most important centre of those States, distant by the shortest route 165 miles north-east from Bangkok, and between which and Bangkok a line of railway has already been commenced by the Siamese Government. Mr. Beckett, however, did not take the usual and shortest route, owing to the fear of want of transport; but crossing to Patriew and Kabin, country districts some 100 miles east of Bangkok, followed the main road leading south-eastwards to Sisophone, near the inland sea of Cambodia, thence by bullock-cart track almost due north across the hill-range, 800 to 1,100 feet high, which encircles the Eastern Laos plateau, and onwards in a north-westerly direction to Korat. The river Moon, or Pramoon, or Peemoon, as it is variously called, which runs from west to east across the Eastern Laos States into the Mêkong River, was forded about ten miles south-east of Korat. After a stay of ten days Mr. Beckett left Korat on January 3, 1892, and journeyed by bullock-cart, across the thinly populated and occasionally undulating plateau stretching between that town and the river Mêkong, almost due north to the important town of Nongkhai on the latter river, lying slightly south of the 18° of north latitude. Ten days were spent at Nongkhai, during which a visit was paid to the interesting ruins of Wiengchan, the ancient capital of a once most extensive kingdom which embraced the whole of the Eastern Laos States in the Valley of the Mêkong. From Nongkhai Mr. Beckett descended the river Mêkong to Kemmarat, a village on the right bank, and striking across by land to Oobone, a town on the Moon River equal almost in importance to Korat, took boat down that stream as far as the rocky barrage at its mouth, and there, changing boats, redescended the Mêkong. Stoppages were made at Bassac, once the capital of a large State, at the cataracts of Lih Pih below the island of Khong, and at Chiengteng, an important Siamese town a few miles north of the Cambodian frontier. After passing many dangerous rapids Mr. Beckett entered Cambodian territory, and taking the steamer of the Messageries Fluviales Co. at Kratieh, the highest point of the river navigable by steamers in the dry season, arrived at Pnompenh, the capital of Cambodia, on March 23. Changing steamers here, Mr. Beckett descended the Mêkong to the sea, and reached the French port of Saigon on the next day, returning thence to Bangkok by way of Singapore. Mr. Beckett arrived at Bangkok on April 4, after an absence of 132 days.

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[1] Published in the *Proceedings of the R.G.S.*

6. *Cadamosto: 'The Marco Polo of West Africa.'* *By* H. Yule Oldham.

Alrise da Ca da Mosto, born at Venice in 1432, entered, like Columbus and other Italians, the service of Portugal, and at the instigation of Prince Henry the navigator made two voyages along the west coast of Africa in the years 1455 and 1456. In the second of these the Cape Verde Islands were discovered for the first time. The journals of these voyages form one of the earliest personal narratives of an explorer, and are of particular value as a connecting link between the periods of Prince Henry and Columbus, the two great figures in the history of geographical discovery in the fifteenth century.

As the trustworthiness of Cadamosto has been seriously impugned, the object of the paper is not merely to draw attention to the merits, but to vindicate the character, of this important traveller.

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7. *North Korea.* *By* C. W. Campbell.

The subject of this paper is a journey which was undertaken by Mr. C. W. Campbell, a member of Her Majesty's Consular Service in China, through the northern half of Korea to the Manchurian frontier in the autumn of 1889.

Starting from Söul, the capital of Korea, on August 31, Mr. Campbell crossed the peninsula by a north-easterly route to Wön-san, the treaty port on the east coast. The interesting portion of this traverse was the Keum Kang San, or Diamond Mountains, which had not previously been visited by a European. They are a notably irregular section of the principal Korean range which descends from the Ch'ang-pai Shan (Ever-White Mountains) of Manchuria, are the head-quarters of Korean Buddhism, and possess some striking scenery which attracts numbers of native tourists every year in spring and autumn.

From Wön-san the route followed the coast to Ham-heung and Puk-ch'öng, where it broke inland to Kap-san and the Yalu River. At Po-ch'ön, a village on a branch of the Yalu, Mr. Campbell procured guides and bearers, and continuing northward through an uninhabited forest, made an attempt to ascend the extinct volcano of Peik-tu San (White-Head Mountain), better known as the 'Long White Mountain,' which is an erroneous translation of the Chinese *Ch'ang-pai Shan*, or Ever-White Mountain. It was first authentically visited in 1886 by Mr. James and his party, who approached it from the Manchurian side. Besides being the centre of much legend and fable in both Manchu and Korean history, the White Mountain is remarkable physically by reason of an Alpine lake which has formed in the extinct crater at 7,000 or 8,000 feet above sea-level. Mr. Campbell just failed to reach this lake in consequence of heavy falls of snow and the illness of his principal guide. The return journey to Söul was varied by re-crossing the peninsula to P'öng-yang. Altogether the ground covered was 1,300 miles, a good deal of which was unknown to geography.

Korea is a hilly country, with poor roads, and worse government. The soil is prolific, but the system of agriculture pursued is lazy and primitive. There are many indications of mineral wealth, alluvial gold being particularly widespread; however, the Government is extremely averse to the exploitation of mines by foreigners, and little or nothing has been done under native auspices. The Korean race is physically superior to the Japanese, and not inferior to the Chinese. The national disposition is bright, good-humoured, and *sans façon*, but improvidence and laziness are prominent negative qualities. Fortunately for Western travellers, the Koreans are not so pronouncedly 'anti-foreign' as their neighbours the Chinese.

[The paper has been published in the 'Proceedings of the R.G.S.']

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8. *On a New Project for Drying-up the Zuyder Zee.*
By Professor P. H. Schoute.

[An account of this project will be published in the 'Proceedings of the R.G.S.']

A joint meeting of Sections B and E was held for the purpose of reading and discussing the following papers on Oceanography:—

(*a*) *New Results in the Density and Temperature of the Bottom Water of the Atlantic off the Brazilian Coast.* *By* J. Y. Buchanan, *F.R.S.*

(*b*) *The Hydrography of the Baltic, the Kategat, and the Skagerak.* *By* Professor Otto Pettersson.

(*c*) *The Physical and Biological Conditions of the Black Sea.* *By* M. N. Andresoff.

(*d*) *The Chemical Composition of Sea Water.* *By* Dr. Gibson.

[An account of these papers will be published in the 'Proceedings of the R.G.S.,' Sept. 1892, p. 625.]

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—The Hon. Sir CHARLES W. FREMANTLE, K.C.B.

THURSDAY, AUGUST 4.

The PRESIDENT delivered the following Address:—

I SUPPOSE that few Presidents of any Section of this Association begin the preparation of their Addresses without taking at least a mental retrospect of the work of their predecessors. I have turned with great interest to the Address delivered by the late Lord Neaves, who occupied this chair in 1871, when the Association last met in Edinburgh. Lord Neaves rightly held that the subject of statistics is ancillary to the main subject of the Section, Economic Science, and his immediate predecessor, the lamented Professor Stanley Jevons, pointed out at Liverpool in 1870 that even 'the name "statistics" in its true meaning denotes all knowledge relating to the condition of the State or people.' I propose to devote the main portion of my Address to a subject to which I have devoted much attention, and which is intimately connected with the welfare of an important section of our people, and I shall hope to point out the means which may be taken to promote their welfare without leading them, as Lord Neaves expressed it in his concluding words, 'to dispense with ordinary and necessary prudence.' It is impossible to exaggerate the change which has taken place since the date of Lord Neaves's Address in the ideas of the public as to its responsibilities in regard to what is called charity. While it recognises that much which was then held to be 'charity' is nothing more than justice to the poorer classes, its sense of the dangers of pauperisation has been greatly intensified, and it justly regards many of the charitable methods which would then have been unhesitatingly advocated as not conducive to their best interests. I venture to claim a considerable part of the change which has taken place as due to the efforts of the Charity Organisation Society, which had then been recently founded, and of which I have the honour this year to be Chairman. I claim that the Society has made men everywhere think, and think seriously, of the duty incumbent upon them, not only of giving, but of giving with care and discrimination, and that it has enlisted in the service of their poorer brethren an army which, besides being always ready to be prudently generous, is in a thousand cases willing to ensure, by personal effort, that charitable help shall be wisely and kindly dispensed. Such personal effort realises what was well described centuries ago in the Talmud as 'the doing of kindness,' and is developing 'a system founded not on rights but on sympathy, dealing not in doles but in deeds of friendship and of fellowship, and demanding a giving of one's self rather than of one's stores.' It has naturally followed that collateral subjects, such as the promotion of thrift and the better regulation of benevolent and benefit societies, have during the last twenty years received a greatly increased amount of enlightened attention.

Before proceeding, however, to the main subject of my Address, let me briefly refer to two questions more directly connected with the special work to which the greater part of my official life has been devoted.

The first of these is the restoration of the gold coinage, a question which has for many years past exercised the minds of successive Chancellors of the Exchequer, and has been a stumbling-block to bankers and the commercial world. It had long been felt that the machinery provided by the law, as laid down in the old proclamations and embodied in the Coinage Act of 1870, was of necessity powerless to maintain the gold currency in an efficient condition. The law provided that 'where any gold coin of the realm is below the current weight . . . every person shall, by himself or others, cut, break, or deface any such coin tendered to him in payment, and the person tendering the same shall bear the loss'; but as there was no penalty for the disregard of this obligation, it became practically inoperative. Gold coins, however much below the least current weight, passed freely from hand to hand, and bankers received them from their customers and paid them away again. Only the Bank of England and a few other public departments obeyed the law, with the result that the principal sufferers were the banking establishments, who in the course of business pay large amounts of gold coin into the Bank of England, and were obliged to submit to the loss on all coins found to be light. The banks, in self-defence, naturally paid in as many full-weight coins as possible and put the light again into circulation. Not more than 1,500,000*l.* of light coin, therefore, was annually withdrawn, and it was calculated that, at last, of the sovereigns in circulation as many as 46 per cent., and of the half-sovereigns no fewer than 70 per cent., were below the least current weight. A Bill was brought in in 1884 for the withdrawal of light coins by the State and for the substitution for the half-sovereign of a ten-shilling piece of the intrinsic value of 9*s.*, so that a fund might be provided to cover the expense of the operation and of the future maintenance of the currency in a proper condition; but this Bill was not proceeded with. Of the subsequent Bills introduced none became law, until in 1889 an Act was passed withdrawing light gold coins of former reigns, and these coins were finally called in under a proclamation issued in November 1890. The entire operation was effected at a cost of about 50,000*l.* It is curious to note that this is the first instance in which gold coin has been decried in this country, for the guinea and half-guinea had never been declared uncurrent, and doctors and others might have contended that their fees were still represented by coins which were legal tender. The Act of 1889, with the subsequent proclamation, having served its purpose by clearing the circulation of all the older gold coinages, there only remained coins of the present reign to deal with. The Coinage Act of 1891 provides for the withdrawal of light gold coin by the State at its full nominal value, and will apply equally to coins which will hereafter become light as to those which have already fallen below the legal weight. No one can now or in the future suffer for tendering a light sovereign or half-sovereign more than for making a payment with a worn half-crown or shilling, and any Victorian gold coin tendered at the Bank of England, provided that it has not been defaced and that its weight has not been fraudulently reduced, is received and exchanged. For the present, coins must be sent in in parcels of 100*l.* It is unnecessary to dwell upon the advantage which these arrangements have conferred, and will confer, upon the public. In 1842–45, when the previous withdrawal of light gold took place, the coin was only paid for by weight at the Mint price of 3*l.* 17*s.* 10½*d.* per ounce, and many were the misunderstandings and bitter the complaints to which the conditions of withdrawal gave rise. No inconvenience or alarm, on the other hand, is likely to attend the measures necessary under the Act of last year, which make it possible to effect the gradual withdrawal of the light coin without friction. To July 1 last the amounts withdrawn were: sovereigns 5,150,000*l.*, and half-sovereigns, 3,850,000*l.* It had been estimated that the average deficiency of weight in each sovereign would be 2·57*d.*, and in each half-sovereign 2·65*d.*, and the actual deficiency found has been 2·65*d.* in the case of sovereigns and 2·93*d.* in the case of half-sovereigns. After the first withdrawals have been effected it is probable that the deficiency will become less, as a certain amount of much worn coin had no doubt been accumulated in banks in anticipation of the passing of the Act. As far as the work has as yet proceeded, however, the cost of withdrawing 1,000,000*l.* in sovereigns has been found to be 11,056*l.*, and of withdrawing

1,000,000*l.* in half-sovereigns 24,418*l.* A sum of 400,000*l.* was set aside by the Act for the expenses of the withdrawal, which will be sufficient at this rate to meet the loss on 26,593,000*l.* Elaborate investigations were conducted by the late Professor Jevons in 1868, by Messrs. Inglis Palgrave and J. B. Martin in 1882, and by the Mint in 1888, with a view of ascertaining the total amount of light gold in circulation in the United Kingdom. Time does not admit of my analysing the results here, and indeed, so far as actual facts are concerned, the problem can never be solved, as a large number of coins become light each year, and the restoration of the currency, therefore, can never be complete. I might perhaps mention, as an interesting fact, that the Mint examination just referred to showed the gold coins circulating in Scotland to be less worn than those in circulation in England and Wales, owing no doubt to the general use in the north of 1*l.* notes.

The other question connected with the currency to which I wish to refer is one which since the last meeting of the Association has been much discussed, and which, though it has not as yet been the subject of legislation, is of primary importance.

In December last the Chancellor of the Exchequer, in an address at the London Chamber of Commerce, described the changes which he thought it would be desirable to make in the currency system of this country for the purpose of increasing the central store of gold. The Baring crisis and difficulties which accompanied it, and in particular the necessity for obtaining 3,000,000*l.* in gold from the Bank of France at very short notice, had drawn the attention of the business community to the fact that the existing metallic reserve was very small in relation to the enormous structure of credit founded upon it, and that it might be found to be wholly insufficient. Mr. Goschen's proposal was to allow the Bank to issue 1*l.* notes, requiring four-fifths of any additional amount of issue so created to be covered by gold, while only the remaining fifth would be allowed to be issued against securities. The effect of this scheme, if 1*l.* notes proved popular, would have been to increase the total amount of the central store of gold, and also to increase the proportion borne by the gold in the Issue Department of the Bank of England to the note-issue covered by it. At the same time the profits upon the fiduciary portion of the additional issue would have sufficed to defray the cost of that issue without additional charge to the public. The Chancellor of the Exchequer considered that if a substantial increase were by these means secured in the gold in the Issue Department, it would be safe to allow the Bank, in times of crisis, an elastic power of issuing further notes against securities, upon conditions stringent enough to secure this privilege from abuse. This elastic power of increased note-issue was intended to take the place of the illegal suspensions of the Bank Act which had on several occasions been found necessary in the past.

This scheme was the subject of much discussion both in the Press and in banking and business communities. There appeared to be a general consensus of opinion that an increase in the central store of gold was very desirable, but there was difference of opinion as to the manner in which that increase might best be brought about. Objection was also felt by many bankers, and by a large part of the general public in the South of England, to the issue of 1*l.* notes.

The conditions of the concluding session of the late Parliament were not favourable for dealing with a large scheme of currency reform, and, as it was evident that the scheme proposed would not receive such unanimous support as would make it possible to pass it without very full discussion and consideration, the Chancellor of the Exchequer did not bring his proposals before the House of Commons in the shape of a Bill.

I make no apology for devoting a large part of this Address to the subject of old-age pensions, although I am inclined to condole with my hearers and myself on the necessity of discussing a question which has now been for many months before the public, and which may by this time be considered to have been worn somewhat threadbare. But the question is surely a great and important one, on

the wise solution of which the welfare of a not inconsiderable part of our population may materially depend, and one, therefore, which should certainly find a place in the discussions of this section of the British Association.

All honour, let me say in the first place, to Canon Blackley, the pioneer of the movement so closely identified with his name and labours! Canon Blackley was, and is, in the opinion of many thoughtful people, only in advance of his age, and deserving of the credit of seeing that without compulsion no system of national insurance worthy of the name can be carried into effect. His scheme, with others subsequently proposed, was considered by a committee of the House of Commons originally appointed in 1885, and reappointed in the Parliaments of 1885 and 1886, 'to inquire into the best system of national provident insurance against pauperism.' The report of the Committee, issued in August 1887, stated that their inquiry had 'practically narrowed itself into an examination of one particular scheme,' namely, Canon Blackley's, 'which had manifestly impressed itself, whether favourably or unfavourably, upon the minds of witnesses, to the exclusion of all other proposals.' It might 'be briefly described,' they reported, as a scheme 'for the compulsory insurance of all persons, of both sexes and of every class, by the prepayment between the ages of 18 and 21 years of the sum of 10*l.* or thereabouts into a National Friendly or Provident Society, thereby securing to the wage-earning classes 8*s.* per week sick-pay and 4*s.* per week superannuation pay after the age of 70 years.' In pronouncing their opinion on the scheme, the Committee first called attention to the evidence they had received from working-men and large employers of labour in favour of enforced contributions to a National Insurance Fund, the latter class of witnesses describing the benefits which had resulted from the establishment of such funds among persons in their own employment. They then proceeded to record the objections to the scheme laid before them from the administrative and actuarial points of view; to the difficulty of enforcing the payments to the fund; to the exclusion of all but wage-earners from benefit; to the discontent which would be felt by the upper and middle classes at being called upon to contribute; and, finally, to the proposal for compulsion, which they considered 'open to very strong objections.' It is clear, I think, that we are not prepared, at any rate at present, for the adoption of so sweeping a measure.

Canon Blackley has, indeed, since expressed his willingness to admit the idea of State aid towards pensions in accordance with the proposals of the National Provident League, with which he is connected; but he appears disposed to admit this and other deviations from his original plan only as stepping-stones towards a general system of compulsory contributions.

I next turn to Mr. Chamberlain's scheme. Mr. Chamberlain and the voluntary Committee of Members of the House of Commons with whom he is associated propose to establish a State Pension Fund, to which Parliament should be asked to make an annual grant, to be supplemented by contributions from local rates. The scheme is applicable to both men and women, and contains provisions for the payment of certain sums into the Post Office Savings Bank before the age of twenty-five, and certain further sums during each of the succeeding forty years, which would entitle men to pensions of 13*l.*, and women to pensions of 7*l.* 16*s.* per annum at sixty-five. There are other provisions for the cases of widows of persons dying before sixty-five, and for other contingencies. There can be no doubt that this is a serious and businesslike attempt to grapple with the problem before us, but it seems open to the objection that it only touches the fringe of the question. By it only the willing fish would be swept into the net, while the too numerous small fry, anxious to elude the cast of the fisherman, whose especial object it nevertheless is to secure them, are allowed to swim away at their ease in the sea of thriftlessness and prospective pauperism. No one who knows the mental attitude and habits of thought prevalent among a large proportion of the working-classes can have failed to note the force of the resistance which they are too often inclined to oppose to any attempt, however gentle, to bring them into the disagreeable position of making definite arrangements even for the immediate future, and of practising anything like systematic self-denial. The inveterate dislike to looking forward, the hopefulness that in some cases seems actually to

grow as misfortunes thicken, the daily evidence that 'muddling on' often does not in fact lead to any decisive or irretrievable catastrophe—all these contribute to encourage a 'happy-go-lucky' existence, and to fortify the belief that without any special effort life may not improbably be lived without great distress, and in due time brought to a fairly satisfactory end. With these fatalistic views and ideas, can we wonder that there is so little thought of the morrow? It is to be feared that such a scheme as Mr. Chamberlain's, notwithstanding the manifest advantages which it offers, would not be widely adopted except by the comparatively small number of prudent people who are already prepared to make the effort necessary to secure a provision for their old age.

Many other schemes of more or less importance and interest have been put forward. Some are ingenious; some appear to contemplate the problem from one point of view only; others are, I had almost said, fantastic. An able and useful work by Mr. J. A. Spender, published in February last, and entitled 'The State and Pensions in Old Age,' with a preface by Mr. Arthur Acland, M.P., discusses the merits of the more important proposals which had then been made, and contains much valuable information.

Among the contributions to the literature of the subject should be mentioned a pamphlet by the Rev. T. W. Fowle, rector of Islip, with the title 'The Poor Law, the Friendly Societies, and Old-age Destitution: a proposed Solution.' Mr. Fowle advocates the gradual extinction of outdoor relief within a period not exceeding twenty-five years, and the allocation to the friendly societies of the sum thus saved, which he reckons, including cost of management, at 3,000,000*l.* per annum, on condition that they should in return guarantee a sufficient maintenance to all their members permanently disabled by sickness or old age. He further proposes that, in consideration of this subsidy, the societies should be required to be, or to become, efficient, and to subject their tables, investments, and rules to the sanction of a Government authority. I do not think the societies would consent to this arrangement. It would doubtless have the eventual effect of putting them all on a solvent basis, except those whose financial position is clearly hopeless, and whose extinction might be contemplated, as Mr. Fowle contends, with equanimity. But such an interference with the affairs of the societies generally would be resented, and their opposition to it, and to any general scheme of pensions which would affect their position and objects, could hardly be considered unnatural or altogether selfish, composed as they are in the main of the flower of the working-classes, keenly alive to the advantages of their independence, and to the evils which any infringement of it might entail.

A striking instance of the feeling in this matter is afforded by the speech of the Grand Master of the Manchester Unity of Oddfellows at the annual Congress of Delegates held at Derby in June last. Speaking of old-age pensions, Mr. Bytheway said:—'For the State to assume that a man in these days was not in a position to earn for himself sufficient to put by to keep himself in old age without assistance from the State would have a most demoralising effect, and would be impolitic on national grounds, and calculated to destroy that independence of character that had done so much in the past history of our country to raise and elevate the people, and encourage thrift upon the only true basis—industry, self-help, and self-denial, and, therefore, to create a strong self-reliance in its train of good results. If the lazy or drunken were to fare alike with the temperate and industrious, this would not encourage thrift; and by giving pensions all round it would certainly not be an encouragement to the better members of society, but would act in a contrary direction. The suggestion that the medium for granting State pensions should be through the agency of friendly societies perhaps more immediately concerned them. As they had built up for themselves a position, and accumulated large funds by the exercise of liberty in managing their own affairs, he would not advise running the risk of losing this liberty and selling their own birthright for a mess of pottage, and having the right of self-management curtailed by any intermeddling on the part of the State, which would be sure to follow if State aid were accepted by them in their aggregate capacity as Oddfellows. Any friendly society accepting such aid would, no doubt, very soon be

subject to State control; in fact, having expended public money, Government would only be doing its duty by claiming complete supervision of the affairs of any society so aided. Whatever form the national pension scheme took, it meant an enormous burden being cast upon the country, and the rate and tax payers would have to supply the means, to a very great extent. The lowest estimate would mean many millions per annum. In fact, the members of the Manchester Unity would be in the position of not only providing for themselves but contributing to a greater number in the aggregate who, through laziness, dissipation, and want of thought to provide for a rainy day, neglected all the opportunities afforded by such societies as theirs, or by any other means, to make any provision at all for the future. This struck at the very root and foundation of friendly societies, and would eventually endanger, if not destroy, all such institutions, as it would be unjust that the careful and watchful should pay for the reckless and vicious, and even be punished by having to provide for their maintenance. . . . He himself thought that any scheme should be self-supporting, and that the public funds should not be drawn upon to provide pensions. The country had been made what it was by individual character, and friendly societies had done very much to form that character among the hard-working population, and might now be regarded as bulwarks of strength to it.'

At another point in the working-man's social scale, we find the following resolution passed by the Executive of the London Dockers' Union in March last. While its political economy is perhaps not so good as that of the Oddfellows, and its language is stronger, it breathes the same spirit of dislike of interference with the management of a Pension Fund:—'That this Executive Committee of the Dockers' Union hereby declares its opinion that any section of Pension Fund not being directly controllable by payees should not be countenanced in any way. We are of opinion, also, that it is an insidious attempt to perpetrate an unjust taxation upon wages. Also a means of retaining a large portion of the workers' earnings for employers' own benefit; while the possible good of such a system is so remote, the longevity of the toilers so low an average, and industrial mortality so high through insufficient wage and unhealthy environment, that we consider it opposed to economic fairness and a curtailment of remuneration, relieving capital and property of burdens at the expense of the already overtaxed and underpaid workmen.'

Nor is the dislike to interference confined to schemes of State aid, for we read that in February last a well-known manufacturing firm in Lancashire offered to subscribe 1,000*l.* a year towards a Sick and Pension Fund for their workpeople, and that the proposal was rejected by a majority of more than two to one, on the ground, no doubt, that it would be prejudicial to the perfect freedom of the latter.

Among the other schemes, Mr. Vallance, the Clerk of the Whitechapel Board of Guardians, the value of whose contributions towards the science of Poor Law Administration and cognate subjects has been so widely acknowledged, suggests that wage-earners should be encouraged to put by small weekly sums, to be met by similar sums contributed, under legal enactment, by their employers, with a view to the formation of a bonus at death, if happening before sixty-five, or of pension after that age. The well-known objection to all such schemes is, that an employer might be tempted in some shape practically to deduct from wages the amount which he would be called upon to contribute.

The proposal of Mr. T. Fatkin, Secretary and Manager of the Leeds Permanent Benefit Building Society, points to the investment of savings, under the management of municipal bodies, in local securities yielding a higher rate of interest than that given by the Government, the compound interest on which at 3 or $3\frac{1}{4}$ per cent. would give greater benefit to the investor. This scheme, again, is one of which it is obvious that advantage would only be taken by persons firmly resolved to make some provision for the future.

I need not specially refer to other schemes which have been recommended, with the exception of that of Mr. Charles Booth, whose views on any subject connected with the welfare of the poor must always command the highest respect. Mr. Booth has made a proposal which from its comprehensive boldness has

astonished many of his admirers, and which, coming from any other quarter, would, I venture to say, have been generally characterised, if not as Utopian, at least as affording to our social and political intelligences, in their present imperfect state of development, no food for serious discussion. It is nothing less, as is well known, than a scheme for universal pensions, or general endowment of old age. With his usual straightforwardness Mr. Booth at the outset informs his readers [1] that, as there are at present 733,000 women and 590,000 men, or about 1,323,000 persons in all, above sixty-five years of age in England and Wales, a universal pension list for those parts of the United Kingdom alone would amount, at 13*l.* each, to 17,000,000*l.* per annum. This sum is reduced by an anticipated contribution of 4,000,000*l.* from the local authorities in consideration of the reduction which would be effected in the rates, and the total amount to be provided by Imperial taxation for carrying the scheme into effect throughout the United Kingdom is estimated at 16,000,000*l.* per annum. Mr. Booth anticipates that such a sum could be raised without difficulty, by direct and indirect taxation, which latter might include increased duties on sugar and drink, 'provided there be any desire that the thing should be done.' I should fear that the means proposed would be quite sufficient to counteract any such desire, and Mr. Booth is unquestionably right in adding that 'if the project does not so far commend itself to the community as to make the necessary sacrifice welcome, no sensible statesman could be expected to take it up.'

But even if there should be any such widely expressed desire, let us see whether the scheme should commend itself in any degree to our matured ideas of self-government or to our long experience of the working of the Poor Law and charitable and other agencies. It is proposed that every man and woman in the United Kingdom should, after sixty-five, receive a pension—duke and dock-labourer, countess and costermonger. Every person, whatever his or her position or antecedents, whether good or bad, rich or poor, thrifty or reckless, is to be treated in precisely the same way. No man, however wealthy or neglectful of his plainest duties to society, however drunken or improvident, as soon as he has reached the magic age, is to be debarred from the right to receive his pension. Is there any merit, I would ask, in living to sixty-five? and cannot a man or woman who has attained that age be almost as great a discredit to society as at any preceding time of life? Surely the mere fact of attaining a certain age should not obliterate the equally certain fact, it may be, that a man's whole career has been a negation of his duty as a citizen and even as a decent human being! Nor can I pass over as futile some of the many objections to the scheme which Mr. Booth mentions, and with which he deals. Among these are, that the hard-working and thrifty would pay for the idle and worthless, and that it is unjust as well as impolitic that the undeserving and those who have done nothing to help themselves should benefit equally with the thrifty and deserving. Mr. Booth contends (I quote his own words) that as 'according to the present law every drunken, immoral, lazy, ill-tempered old man or woman now existing has a right to demand the shelter of the workhouse,' there can, therefore, be no harm in according to such people a weekly allowance of five shillings, which is in effect less than they would cost in the workhouse. I think the difference between the two cases is obvious. The financial results of each arrangement, to the payer of rates and taxes, may be nearly identical, but surely we ought to look further than this and see to it that the deserving citizen is not confronted with the spectacle of his undeserving brother living upon an allowance which he has done nothing to earn, in as perfect freedom as himself, and with every advantage, so far as the law goes, which he himself enjoys. I do not think this would be a very edifying state of things, nor one likely to promote thrift. To this second point Mr. Booth only answers that 'it is even more subtly dangerous to inquire into a man's character than into his means, if the benefit to be received is to be kept free from all taint of pauperism.' I confess that it disturbs me little, as I conceive it would disturb our disreputable friend still less, to add the taint of pauperism to the many worse taints with which

[1] *Pauperism—a Picture; and Endowment of Old Age—an Argument.* London (Macmillan & Co.), 1892, p. 64.

he has been polluted, and to which he has become indifferent, during a long and ill-spent life. If he could look forward to his pension, as Mr. Booth proposes, would he feel a glow of moral superiority and of conscious pride in his manhood? Hardly. His motto would only vary the Epicurean 'Let us eat and drink, for to-morrow we die' to 'Let us eat and drink, for to-morrow' (that is, when we complete our sixty-fifth year) 'we shall get pensions of 5*s.* a week.' But in regard to his prospective pensioners generally, however deserving, Mr. Booth admits 'that a provision for old age, obtained compulsorily under the law, and paid out of taxation, would carry with it none of the moral benefit which would attend the winning of a pension by direct personal sacrifice . . . nor would it directly minister to independence of character,' though he contends, in a somewhat too sanguine spirit as it appears to me, 'that no one would make less voluntary effort to save because of it, and that many would increase their exertions in this direction.' I should have thought that, on the contrary, looking to the widespread inclination to prefer provision against sickness to insurance for old age, which is a well-known feature in the habits of the working classes, and to which the arrangements of the friendly societies bear such striking witness, the mere fact of having a pension of 5*s.* a week to fall back upon would be sufficient to deter most of them from making further provision for the declining years which they may never live to see. Granted, however, that the advantages of a universal pension scheme from taxation were fully shown, there still remain several points touched upon by Mr. Booth which should make the cautious mind pause before consenting to its adoption. For instance, Mr. Booth says: 'It is not to be forgotten or disguised that year by year the sum needed' (for pensions) 'must steadily increase, faster very likely than the rate of increase of the whole population. . . . Happily, wealth is increasing faster than population.' When it is considered that the initial cost is estimated at 16,000,000*l.* per annum, this is a very disquieting suggestion, and quite sufficient in itself to make the boldest hesitate before plunging into such a sea of uncertainty. Then the administrative details of carrying the scheme into effect would necessarily be somewhat complex; and Mr. Booth shows that, when the official army of registrars and superintendent-registrars has been set in motion, the arrangements for fixing the age of the applicant made, and the precautions against fraudulent claims in two places taken, a great deal of difficult and harassing work will have been done. He contends, indeed, that the system is simple as compared with any scheme of national insurance, but he says enough to show that, as might be expected, a very considerable amount of trouble both to officials and claimants will be inevitable. And, finally, he makes no provision for the expenses of the scheme, which, he thinks, need not exceed from 10*s.* to 20*s.* in each case, suggesting that this amount 'could be deducted from the first payments of pension, at the rate of 2*s.* 6*d.* a week till paid.' It is to be feared that, looking to the necessity which there certainly would be, especially in towns, of keeping a constant watch over each case to prevent fraud, such as the drawing of a pension after the decease of the pensioner, the services of registrars would be in pretty continuous demand, and those services would have to be paid for.

But it may be said that national pension schemes have been set on foot in other countries, and that there is no reason why we should be behindhand in the good work. It is true that in Germany three insurance laws have been passed, and according to Mr. Wilhelm Bode—whose article in the 'National Review' of March last should be read by all interested in the question—the latest, that for old age and sickness, is by far the most unpopular. It is generally called the 'Klebegesetz,' or 'Sticking Law,' from the immense number of stamps which it is necessary to use in carrying its provisions into effect, and its administration appears to have been found intolerable. A report on the working of the law during the first year (1891), made by Herr von Bötticher in the German Reichstag in February last, shows that there were 173,668 claims for old-age pensions under this law during the year, of which 132,917 were allowed, the average amount of pension being 125 marks, or 6*l.* a year. It is to be observed that these persons obtained pensions without having contributed anything to the insurance fund. Mr. Bode states that

Herr von Bötticher congratulated himself that a larger number of persons called upon to insure had not absconded, and that the discontent caused by it was not greater, adding that no wish was felt in the country for a continuation of social reform laws. This latest social law certainly does not appear to have been attended with encouraging results. Already a popular movement for its repeal has made some way in Bavaria, but there is of course but little prospect of getting rid of it at present. Meanwhile the self-help societies have either ceased to exist or have been greatly crippled, and Mr. Bode can only hope that they will one by one come back, and that the energy of German manhood, sapped by the compulsory system, will return, and the dishonesty which it fostered die out. His article concludes with an earnest appeal to England not to encumber herself 'with any big scheme of any impatient State socialist,' but to remain, 'what she has been so long, the chosen land of the free—of the men who help themselves.' I think such an appeal should touch us nearly.

In June 1891 a Bill was presented to the French Chamber of Deputies by M. Constans, then Minister of the Interior, and M. Rouvier, Minister of Finance, for the creation of a 'Caisse Nationale des Retraites Ouvrières,' or pension fund for the benefit of workmen and others employed in trade, farm labourers, and domestic servants of both sexes, whose income does not exceed 3,000 francs (120*l.*) per annum. All persons in this position will be considered to be willing to take advantage of the benefits of the fund, unless they make a declaration of unwillingness before the mayor of their place of residence. It is proposed that the fund should be formed by equal contributions from the depositor and his employer, which are either to be paid into the newly established 'Caisse,' or into duly authorised provident societies already existing, and by an addition to be made by the State equal to two-thirds of those contributions. The latter are to consist of not less than five centimes nor more than ten centimes per working-day contributed both by the workman and his employer; and, taking the average number of actual working-days in the year at 280, so as to allow for holidays, slackness of work, and sickness, it is calculated that, after thirty years of continuous saving, five centimes per day put by from each source, and invested at 4 per cent., should amount to a pension of 180 francs, and ten centimes per day to a pension of 360 francs, per annum. These amounts not being considered sufficiently high to tempt the class whom it is desired to benefit, it is proposed, as mentioned above, that the State should materially add to them. The term of years over which the contributions are to spread is limited to thirty, as, owing to compulsory army service, it is considered that contributors will hardly have settled down to steady work before the age of twenty-five, and that but few persons would be willing to continue the necessary payments beyond the age of fifty-five or fifty-six. On arriving at the time for pension, the contributor must be able to prove that his income is not more than 600 francs per annum. The Bill also contains provisions for life insurance, the State contributing towards the payment of the annual premiums; for the payment of their pensions to contributors who have become permanently incapacitated through sickness; and for the relief of those who may be obliged on account of accidents to interrupt their payments into the fund. Several other Bills have been brought forward by independent deputies with analogous objects, into the details of which time will not permit me to enter. It is interesting, however, to note that some of the methods proposed for raising the funds necessary to enable the State to grant pensions are hardly such as would commend themselves to our ideas; as, for instance, the proposal in a Bill presented by several deputies that all collateral successions to property should be suppressed, and that a sliding scale of succession duty should be fixed, rising from 1 per cent. on sums below 10,000 francs to no less than 75 per cent. on sums above 1,000,000 francs. Hardly less interesting is the suggestion of another enthusiastic legislator that, at the central office of the pensions department, to be placed in the Louvre, there should be a museum in which a 'golden book' should be kept for inscribing the names of donors of not less than 100 francs to the pension fund, while the generosity of donors of 10,000 francs should be recorded on a marble tablet, and that of princely subscribers of not less than 100,000 francs by a bust.

In Italy the question of establishing a National Pension Fund has also been widely discussed, and in past years several schemes have been proposed to the Legislature. A Bill is now before the Chamber providing for the establishment of a central governing body, whose duty it would be to administer funds partly subscribed by authorised savings banks or other self-help societies and by individuals, and partly by the State from various specified sources. Every Italian, man or woman, certified to belong to the working-classes, may subscribe to the fund, but not more than 500 lire, or 20*l.* per annum, and every person who has subscribed for not less than twenty years is to be entitled at sixty to a pension, the amount of which is to be determined by the amount of the contributions made to the funds with the addition of compound interest. No pension may exceed 20*l.* per annum. Provision is also made, in the case of the subscriber's death, for the payment to his representatives of all contributions and interest. It is evident that this scheme does not go very far in the direction of establishing a general Old-age Pension Fund.

In April 1891 the Danish Legislature passed a law giving every Danish subject, man and woman, the right to a pension at sixty years of age. Exception is made of persons who have been convicted of crime, who have fraudulently made over their property to relatives or others, who have brought themselves to distress by extravagance or evil-living, who have during the preceding ten years received relief from the poor-law (*assistance publique*), or who have been convicted of mendicity. Applications for pensions are to be addressed to the parish (commune), who will make all inquiries, and fix the amount of the relief to be granted, which may be in money or in kind. The relief may be withdrawn if the pensioner should become ineligible through misconduct or spend his pension improperly, and, if he marries, his pension is *ipso facto* withdrawn, and he becomes chargeable to the poor-law. It will be seen, therefore, that there is in Denmark no sentimental objection to an inquiry into an applicant's moral character and pecuniary position such as Mr. Booth so strongly deprecates, and that the so-called pensions are but an extension of the system of what we should call outdoor relief. The pension is to be derived from the parish, subject to certain conditions as to the applicant's place of birth, or, if the place of birth cannot be determined, from the poor-law, and the State contributes half the expenses of the parishes in distributing the relief, provided that those expenses do not exceed one million crowns (55,000*l.*) in each of the years 1891–95, and two million crowns (110,000*l.*) in subsequent years. No appeal lies against the decision of the communal authorities.

It is evident that, as only one of the three schemes last mentioned is in actual operation, they cannot as yet be fully judged, but I venture to question whether there is anything which we could think of following here. In this country there is, no doubt, a holy horror of the workhouse, but there is also a perhaps unreasonable prejudice in favour of 'going as you please,' and a scarcely less pronounced aversion, upon the whole reasonable and certainly characteristic, to being what the French would call 'administered.' I can hardly imagine my countrymen, of any class or disposition, subjecting themselves to a regular system of Government interference in affairs of which the management, or mismanagement for the matter of that, they have always considered to be a Briton's birthright. Let us ask ourselves, after looking at the question in all its bearings, whether we must not give up the idea of anything like compulsion in matters of thrift, if indeed we must not also give up the idea, when it came to the point, of anything in the nature of Government help and intervention.

But is there, then, no way in which help can be rendered to our deserving poor? Must the present state of things go on, and the public conscience continue to be shocked at the sight of thousands of old people lapsing hopelessly into pauperism? Let us examine the present state of things, and look a little into its causes. How is old-age pauperism brought about? There is doubtless a not inconsiderable part of our population which might make at least some provision for old age, but which prefers the careless living from hand to mouth, and considers subscription to a burial club the only claim which the future has upon it. As I have already said, even

where there is some thought of the morrow, inveterate habit leads many bread-winners to think more of the immediate than of the comparatively distant future, and to provide rather against the risk of accident or illness by joining a sick-club than against the remote prospect of destitution when the day of work is over. When all this is conceded there must remain, no doubt, many cases of unforeseen and undeserved misfortune, in which old age overtakes the toiler without his having had a chance of making provision for it—cases where wages have hardly ever been such as to allow of saving, where families have been large and sickly, where the struggling widow, work and pinch how she might, has had difficulty in keeping the wolf from the door. These are the hardships with which we must all sympathise—these are the sorrows we should all wish to relieve. Putting unavoidable misfortune aside, however, for the moment, let us consider whether our present system is such as to offer the maximum amount of encouragement to self-help and self-reliance, and the minimum amount of encouragement to an easy-going frame of mind which looks forward to pauperism with equanimity. What are the prospects, generally speaking, of the average worker who has made no provision for his old age? He sees the system of outdoor relief in full operation; he knows that unless and until he becomes utterly helpless and friendless, a dole will be made to him which will keep him from starvation, and he learns to look forward to that dole without repugnance and without dismay. The circumstances under which it is allotted to him make but little change in his family arrangements. His able-bodied children, if he has any, are seldom called upon by the Guardians to make any great sacrifice for him, and he sinks down into a more or less contented, but complete and hopeless, pauperism. I say that a community which tolerates and maintains such a system incurs a grave responsibility, and, so long as it makes no effort to improve it, has no right to wax impatient at the crying evil of old-age pauperism. And if a change in the system is possible, surely we ought to consider whether it cannot and ought not to be made before we seek by heroic measures to set aside arrangements susceptible of gradual improvement and substitute for them a state of things which would perpetuate many of the worst evils of dependence. If we had reason to believe that the Poor Law could only be administered in the manner indicated above, we should perhaps be justified in at once looking outside it for means to improve the condition of our aged poor. But the very reverse is the case. We have abundant evidence that by firm and patient administration the condition of whole districts in regard to pauperism may be radically changed, to the great benefit, material and moral, of the poorer inhabitants. During the last twenty years experiments in this direction have been made both in urban and rural districts, not conceived in the spirit of empiricism or caprice, but undertaken as the result of ripe experience and with a single eye to the real interests of the poor, which have been attended with complete success. The tendency of the reforms effected has been, as is well known, towards a great reduction, and in some cases the total abolition, of outdoor relief. In the winter of 1869–70 the Guardians of Whitechapel, one of the poorest districts in London, had forced upon them the necessity of reviewing their position. Up to that time, in the words of Mr. Vallance, the Clerk to the Guardians—

'The system may be said to have been that of meeting apparent existing circumstances of need by small doles of outdoor relief, the indoor establishments . . . . being reserved for the destitute poor who voluntarily sought refuge in them. Able-bodied men who applied for relief on account of want of employment were set to work under the Outdoor Relief Regulation Order, and, in return for such work, were afforded outdoor relief in money and kind. Under this system, the administration was periodically subjected to great pressure; so much so that the aid of the police had not infrequently to be invoked to restrain disorder and afford necessary protection to officers and property. Police protection was even at times required for the Guardians during their administration of relief.'

In such circumstances, it is not to be wondered at that the Guardians should have earnestly endeavoured to reform 'a system which was felt to be fostering pauperism and encouraging idleness, improvidence, and imposture, while the "relief" in no true sense helped the poor.' They gradually restricted outdoor

relief in 'out-of-work' cases, and subsequently in other cases also. Sick persons, widows, and the aged and infirm were only relieved out of the workhouse on conditions strictly applicable to their individual cases. The latter class were not so relieved unless it was proved that they had been thrifty and had no children or other relatives legally or morally liable to support them and able to do so, and even they ceased to be a charge on the rates after the establishment of the Tower Hamlets Pension Fund, which was formed for the express purpose of saving the really deserving poor from the Poor Law. The result has been that outdoor relief has gradually ceased to exist in Whitechapel, and that no cases, other than those of sudden or urgent necessity relieved by the relieving officer in kind, have been added to the Outdoor Relief lists for more than twenty years. Notwithstanding this, the number of indoor paupers has not increased. Inquiry was made into every case in which outdoor relief was withdrawn during the two years ended Lady Day 1875, from able-bodied widows and deserted women, the most helpless of all classes, with the result that out of 167 cases, comprising 600 individuals, 77 were found to be doing as well as or better than when in receipt of outdoor relief without further assistance, 52 were obtaining an independent living after having received assistance from charitable agencies or other sources, 10 had been admitted to the workhouse, 18 had apparently left the district, two had died, and eight only, owing to vicious habits or the refusal of the assistance offered, were believed to be not doing well. It will thus be seen that of the 167 cases no less than 129 had been taken from the ranks of pauperism, with the best results to themselves, to say nothing of the ratepayers, and with moral results to the community at large which cannot be described in detail here, but which must be obvious. Mr. Loch, the Secretary of the Charity Organisation Society, in his work 'Old-age Pensions and Pauperism,'[1] has given details showing what the results have been of a similar Poor Law policy in two other poor Metropolitan Unions, Stepney and St. George's-in-the-East, the latter, taken as a whole, being the poorest of all the Unions in London, and comparing them with the Unions of the Strand and Bethnal Green. He has also shown the results of careful administration in Unions the very opposite to the London districts abovementioned, namely, the rural Unions of Brixworth in Northamptonshire and Bradfield in Berkshire, as compared with the two similar Unions of Linton in Cambridgeshire and Midhurst in Sussex. The facts brought out by these two sets of comparisons are striking and conclusive. In Unions in which there has been a careful administration of the Poor Law for a period, more or less, of twenty years, it has been proved that the proportion of paupers over sixty to population can be reduced in the country to about four per cent., and in London, judging by its poorest Union, by more than half the present number. Can it be doubted that in these cases the bugbear of old-age pauperism has already been faced and in a great measure dispelled, and is there any reason, beyond the force of habit and a *vis inertiæ* which surely might be grappled with, why both town and country Guardians should not follow the example set them by the pioneers of this movement, and by a common effort subdue the common enemy? Let us not, with the experience we have to guide us, be led astray in this matter, though some of our philanthropists and political economists seem inclined to countenance a large increase of public expenditure in connection with the relief of the poor. Among the many nostrums for the cure of the disease under which the State is supposed to labour is a proposal by Mr. Bartley, M.P., embodied in the 'Old-age Provident Pension Bill' which he brought in during the last session of Parliament. Mr. Bartley proposes that every person (man or woman) of sixty-five, who is not a criminal or drunkard, and who is unable to earn the wages of his calling, shall be entitled to a pension of 7*s.* per week from the local authority, which is to be the County Council, provided that he has never received poor-law relief. If he has purchased an annuity from the Post Office or some friendly society, or paid a lump sum for the purchase of a deferred annuity from the Post Office, or is prepared to pay a lump sum of not less than 10*l.* to the

[1] *Old-age Pensions and Pauperism.* An Inquiry as to the Bearing of the Statistics of Pauperism quoted by the Right Hon. J. Chamberlain, M.P., and others in support of a scheme for National Pensions (London: Swan Sonnenschein & Co., 1892).

local authority, or has partially provided for himself in other ways, to the satisfaction of the local authority, he is to be entitled to a pension of 3*s.* 6*d.* per week, with the addition of an extra amount according to the payments which he has made. And, further, there are to be pensions, if the local authority should see fit, of 3*s.* 6*d.* per week even for the persons declared ineligible, provided that they can show unavoidable illness or misfortune. The necessary funds are to be raised by a special rate to be called the 'Pension Rate.' I need not do more than call attention to these provisions to show how disastrous such a law would be. The burden which would be imposed on the County Councils of deciding upon the merits or demerits of each case; the wide discretion allowed in the award of pensions, even to the criminal and drunkard, if only what can be construed into 'unavoidable misfortune' can be proved; and the danger that absolutely different constructions of the law would prevail in different localities—all combine to make it next to impossible but that its operations should be fatal to the exercise of thrift, and should bring back in redoubled force many of the evils of extensive outdoor relief, with greatly increased burdens on the ratepayer. Among the political economists I regret to say that an eminent professor, and, what is more (I speak with bated breath), a former President of this Section, has thrown his great weight into the scale of wide, if not lavish, distribution of outdoor relief. I am not quite sure that I understand Professor Marshall's position, but he propounds in the 'Economic Journal' sixteen questions which he thinks should be considered before any large scheme is undertaken for the relief of the aged, and which seem incidentally to show his antagonism to most of what I had thought to be the generally accepted maxims of poor-relief.

But let it not be supposed that advocates of a firm and careful administration of the Poor Law consider it the only thing required to prevent or deal with all cases of old-age pauperism. In the best-regulated Unions, especially in towns, there will always be cases—too many, alas!—of highly deserving old people who are unable to maintain themselves, and of whom no just person could bear to think as condemned to outdoor relief, and still less to incarceration in a workhouse. These are precisely the cases which are best brought out where outdoor relief has either been entirely abolished or is quite the exception. For these—and experience in well-managed Unions has shown how comparatively few they are—there surely remains the exercise of a well-ordained charity which will step in and prevent a consummation so much to be deprecated. Children and other relatives, who under a loose system of poor-relief are too apt to consider that in one shape or other their parents and aged kinsfolk may naturally be left to the tender mercies of the Poor Law, are brought together and induced to contribute to their support; and pension societies, such as the Tower Hamlets Pension Committee, the Local Pension Committees of the Charity Organisation Society, and the like, are willing and anxious to come to the rescue. Nor is this organised assistance to those whom the late Duke of Albany called 'the aristocracy of the poor' of use to the recipients only. In hundreds of cases which have come under my own knowledge in East London, for instance, it has been the means of inspiring in men and women a holy zeal for charity which, without any hateful feeling of patronage on the one side, or of cringing dependence on the other, gives a scope, such as none other can supply, for a true friendship between rich and poor and blesses both the giver and the receiver. I have endeavoured to show, in these few and necessarily brief remarks about one of the great social questions which occupy men's minds to-day, that for the promotion of the best interests of our aged poor there may be a 'more excellent way' than a vast organisation of State-aided pensions. May we work out this and other similar problems, as Englishmen do, calmly, wisely, and to good effect!

But, turning to our immediate duty as members of this Section, let us endeavour to ascertain what we can do to inculcate and foster sound views on these and similar subjects. In the proceedings of this British Association for the Advancement of Science we may see how intimately the work of Section F is

related to that of the Sections in which the physical and mechanical sciences are studied. The extraordinary advances which have of late years been made in the application of science to industry have materially added to the wealth of the working-classes, and that wealth is more easily earned than in the past. But their knowledge of the great economic laws upon which true progress must depend has not kept pace with their increased resources; nor can this be the case until they are able to grasp the principles of our subject. It may fairly be urged that the advance in physical science is drawing its relations to economic science closer day by day. May we not be about to witness some of the enormous developments caused by the substitution of machinery for hand-labour which we have for some time past been led to expect? The rapid exhaustion of coalfields, to which Sir Robert Ball has recently again called attention, is leading to the utilisation of power from other sources, a question with which the President of Section G will doubtless deal. We are told that the falls of Niagara develop a force of $4\frac{1}{2}$ million horse-power, or the equivalent of all the steam-power used in the world, and that steps have been taken for the immediate utilisation from this source of 100,000 horse-power, or the equivalent of one forty-fifth part of the steam-power of the globe. Advances such as these in the utilisation and transmission of energy must, by extending the means of production, profoundly affect the wage-earning capacity of the workman, and consequently the general relations between employers and employed; and it is the privilege of members of this Section to prepare their countrymen for the altered condition under which they may be called upon to live and work. They must never be weary in setting before all sections of the community the necessity of being ready to face such momentous changes as those which I have indicated, and, if I may be permitted to borrow an illustration from electrical science, I would say that their duty is analogous to that of the 'transformers,' of which so much has lately been heard. They deal less with energy itself than with its control, but their function is so to change forces of unwonted 'potential' that those forces may cease to be dangerous and disruptive, and may be made to weld the various efforts of humanity into coherence and strength.

The following Papers were read:—

1. *Methods of Social Inquiry.* *By* Professor P. Geddes.

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2. *La Science Sociale et sa Méthode.* *Par* M. Demolins.

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3. *Some Notes on the Compilation of Monographs on the Economics of large Cities, with Illustrations from the Case of Glasgow.* *By* Prof. James Mavor.

1. Description of plan of operations.
2. Classification of statistics involving modifications of systems of classification adopted by Engel and Le Play.
3. The industry as the unit of investigation.
4. The family as the sub-unit.
5. Miscellaneous character of the industries of Glasgow, and general account of the chief industries.
6. Conditions of life among artisans employed in the chief industries.
7. Examples of family monographs.
8. The practical utility of such investigations.

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4. *The Slums of Manchester.* *By* Chas. W. Smiley, *M.A.*

A fair sample of the Manchester slums is the tract on Oldham Road recently taken by the Corporation. It contains 173,800 square feet, or about three acres.

In 189 dwellings resided 954 persons, of whom 114 were under five years of age. The density of population was 240 per acre, as against 64, the city average. The death-rate has crept up to an average of over 50 per 1,000 for the past four years, as against a city average of only 18 per 1,000. The buildings (two-story brick) in this area were mostly erected before 1830, were very deficient in ventilation, and had become so unsanitary as to be condemned by the medical officer of health. Over ninety of them were back-to-back houses. The Corporation will clear the whole tract, and erect a five- or six-story apartment house thereon, similar to the Jersey Street dwellings in Manchester. These dwellings were constructed in 1891-92 by a private company. The building is 176 feet long, 48 feet deep, and six stories high; is fireproof, and provided front and rear with balconies for providing access to the 149 apartments. Excellent ventilation is secured. A resident superintendent enforces a set of rules which are made necessary by the circumstances, but which incidentally are of a very civilising character. Cleanliness and self-control become a necessity to the tenant. As no tenant can sublet, overcrowding—one of the worst features of slum life—is impossible. The conduct of the tenants is sufficiently under the guidance of the superintendent to insure health and happiness to a considerable degree. Certain voluntary societies organised among the tenants, it is hoped, will have a further influence for good among them.

Whenever, therefore, a slum gets so unhealthy that it can be condemned as unhealthy, the way is open to forcible interference by the municipality. If such buildings can be made to pay, they will of course multiply through private enterprise, and a demand for sanitary dwellings may perhaps be cultivated among the denizens of the slums.

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5. *Parliamentary Returns on Social and Economic Subjects.* *By* C. S. Loch, *B.A.*

Figures are used every day as 'decisive and conclusive arguments,' as means of agitation, or as means of instruction. We have to deal especially with figures as they are drawn up in parliamentary returns. One out of many instances of the misuse is quoted. In 'Facts for Londoners' the Fabian Society publish, by way of agitation, such statements as the following:—'In London one person in every five will die in the workhouse, hospital, or lunatic asylum. In 1887, out of 82,545 deaths in London, 45,507 being over twenty, 9,399 were in workhouses, 7,201 in hospitals, and 400 in lunatic asylums; or, altogether, 17,000 in public institutions.' 'One in every three London adults will be driven into these refuges to die.' 'One in eleven of the whole metropolitan population is driven to accept Poor-law relief during any one year.' 'In spite of all, twenty-nine deaths were referred in 1888 to direct and obvious starvation.'

Deaths in Public Institutions.—'Workhouse,' in the Registrar-General's returns, includes Poor-law infirmaries and the district hospitals of the Metropolitan Asylums Board for infectious diseases. Without explanation the reader would not understand this. The evidence taken by the Select Committee on Hospitals shows that the poor are not driven to these institutions to die, but go only too readily. Nor are people driven to die in lunatic asylums, which, like the district hospitals, are provided for the general benefit of the community. Figures show how, since 1867, when the Metropolitan Poor Act was passed, there have been very many fewer deaths in workhouses, and a larger proportion in the Poor-law infirmaries and hospitals and asylums of the board. And 'hospital' in the Registrar-General's return includes such different institutions as the Herbert Military Hospital and a cancer hospital, &c.—institutions not to be 'put under one hat.' Artisans who earn good wages are rightly in long illness in-patients at these hospitals, and they contribute to them, as the Hospital Saturday Fund lists show. Besides, many hospital cases are accidents. The argument of 'the facts' comes to this, that the better our medical provision, the worse our social state. The figures, too, are incorrect. London institutions outside the metropolitan division are not included. Nor is allowance made for non-Londoners dying in London institutions. Lastly, the return is misapplied. The object of it was to show what allowance was to be made

for deaths in institutions in census returns; and whether, comparing year with year and hospital with hospital, hospital mortality could be prevented or reduced.

The 'Starvation' Returns.—'Twenty-nine cases were referred in 1888 to direct and obvious starvation.' The figures for 1888 were the smallest then on record. This is not noted. It is a common error to take one year's returns only and to ignore the historical context of a return. Further, cases, as entries in the returns show, are not due 'to direct and obvious starvation,' but to many other causes besides. The correctness of the verdict, too, is sometimes very doubtful, as instances show.

The Poor-law Returns.—'One in eleven of the whole metropolitan population is driven to accept Poor-law relief.' This includes admission to Poor-law infirmaries, lunatic asylums, and the idiot and imbecile asylums of the Metropolitan Asylums Board, and so on. So that the statement, as it stands, is quite misleading. Besides, probably 2, and not $3\frac{1}{2}$, is the multiplier to obtain, from the number of paupers in a day, their number in a year. The multiplication by $3\frac{1}{2}$, a moot point, is known to be very doubtful.

Conclusions: that returns should not be used without reference to their historical and social context, and should be analysed before use so that the reality of their definitions may be tested, and differences as well as similarities in the units on which they are based clearly shown.

The Compilation of Returns.—The need of more care in the compilation of returns is shown by reference to Mr. Burt's return of aged paupers, the recent return (May 1892) on the same point, and the yearly and day census of pauperism, Lord Lymington's return on the number of members of friendly societies who are paupers, and the return of the Charity Commissioners on the application of charitable funds to elementary education. It is suggested that when, on general grounds, it has been decided to compile a return, the form of it might be settled by a select committee after taking expert evidence; that if the information desired cannot be supplied, as evidence might show, in the form of a return, the proposed return might be abandoned; that some kind of preface might be affixed to a return, showing (1) the method on which it was compiled; giving (2) explanatory matter, as, *e.g.*, supplied by the Local Government Board in their Appendix E; and (3) references to previous returns of a similar nature; also (4) short accounts of the official proceedings in certain returns, *e.g.*, the 'starvation' returns. A complete catalogue and subject index might be compiled of papers in some departments of social work by such a society as the Statistical Society.

Limitation of the Returns System.—Many returns at every point touch the domain of character. It is a question whether we do not err in classifying, *e.g.*, by wages, &c. (*cf.* the classes A, B, C, &c., of Mr. C. Booth's tables); and whether we would not get truer results by analysing or counting by types. Social science can show few results of long-continued impartial investigation such as in natural science can frequently be found.

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6. *The Relation of Ethics to Economics.* *By* J. S. Mackenzie, *M.A.*

Political economy, being a practical science, falls entirely within the sphere in which ethical considerations apply, and it is consequently affected by ethics at every point; but the chief points of contact may be conveniently summed up under four headings :—

I. *The Place of Economics in Social Science.*—Political economy has had an exaggerated prominence, which, from an ethical point of view, cannot be justified. This prominence is partly due to the recent development of industrial life, and partly to the fact that economic study lends itself more readily to abstract treatment than the other aspects of social life. An effort must be made to correct this one-sidedness, and to treat economic questions in subordination to questions of social well-being in the larger sense.

II. *Economic Methods.*—There are, broadly speaking, three different methods of economic study :—(1) The historical method, considering what is and has been. (2) The analytic method, investigating what tends to be. (3) The moral method, endeavouring to discover what ought to be. Without disparaging the two former

methods within their own limits, we must insist on the subordination of the study of what is, and what tends to be, to the study of what ought to be. And at least the three studies must be carefully distinguished.

III. *The Divisions of Economics.*—Regarding production, distribution, and consumption as the chief departments of economic science, we have to notice a tendency to give undue prominence to production. From an ethical point of view, we must insist on the importance of distribution and consumption. Also production must be studied, not merely with reference to the thing produced, but also to the person producing. With regard to consumption, we have to consider the effects of different kinds of consumption: (1) on the well-being of the consumer; (2) on that of the producer. The importance of this side of economic study has been partly obscured by the Utilitarian theory. The theory of value has been somewhat obscured in the same way. Objective values must be studied as well as subjective.

IV. *Applied Economics.*—Political economy is an art as well as a science, and it is chiefly in its aspect as an art that it is affected by ethical considerations. In applying economics to the guidance of conduct, it is necessary to consider the question of justice. On this subject recent ethical thought has thrown an important light by the introduction of the conception of the organic unity of society. The conception of justice thus reached may be opposed to the conceptions of abstract freedom and abstract equality. The chief thing to be insisted on, from this point of view, is that everyone must be treated both as means and as end. We arrive in this way at two great commandments:—(1) Thou shalt not exploit. (2) Thou shalt not pauperise. The application of these principles in detail is by no means easy. It is a problem that will require the same strenuous application as that which has already been devoted to questions of production and exchange.

FRIDAY, AUGUST 5.

The following Papers were read:—

1. *Old-age Pensions.* *By* Rev. W. Moore Ede, *M.A.*

Pending promised information by Local Government Board, Mr. C. Booth's reduced estimate is that 25·9 of population over sixty-five apply for relief each year, and 30 per cent. who reach sixty-five are paupers before they die. A large amount of suffering of the aged not included in these figures.

The Poor-law refuses all help to those not absolutely destitute. The unskilled labourer cannot save enough to support himself entirely, so bad policy to save anything.

The reform needed is such a change of method as will render it possible for everyone to make provision for old age if he will.

Insurance presents many practical difficulties, of which irregularity of employment and cost of working are chief, and would not touch the poorest.

Mr. Chamberlain's scheme is right in suggesting that cost of pension should be borne to extent of one-half by taxation.

Endowment, as suggested by Mr. C. Booth, would be too costly, as to give everyone over sixty-five 5*s.* a week would require raising 16,000,000*l.* extra taxation.

Everyone does not require such help. To give three who can do without it a pension in order to secure that the fourth shall have it on sound principles may be logical, but is not practical.

The reader's suggestion is to combine the principle of Mr. Chamberlain's scheme to the extent of throwing half the burden on taxation with Mr. Booth's endowment proposal, and give 2*s.* 6*d.* a week to everyone over sixty-five whose income is less than, say, 50*l.* per annum. Every man would be left free as to how he found his half of the pension. Those who could do nothing for themselves would be

compelled to accept relief in the workhouse. The cost would not be formidable —not more than from 5,000,000*l.*

The principle might be extended to all permanently incapacitated from earning their living.

The nation now endows destitution. What is required is that the nation should endow thrift.

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2. *The Poor-law: can it be Maintained?* *By* Rev. T. W. Fowle, *M.A.*

The Poor-law of 1834 is on its trial, serious humanitarian, political, moral, and economic difficulties arising out of it. It was a sharp remedy for evils now passed away. Impossibility of altering it upon less stringent lines without destroying the scientific basis upon which it stands, and to which it owes its value. Hence need and opportunity for a new system. Analogy of educational system and of uncommon English methods.

Proposition to do away with out-relief and co-operate with friendly societies, making them responsible with State subvention for the relief of all disabled persons being members. Club test instead of house test. Improvement in friendly societies much needed, and would follow.

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3. *Old-age Pensions and Friendly Societies.*
By Rev. J. Frome Wilkinson, *M.A.*

I. Provision for old age through the friendly societies.
II. Pensions for old age through Poor-law relief.
III. State insurance schemes examined, with a special view to their relations to friendly societies and Poor-law relief.
IV. State endowment schemes.
V. Conclusion.

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4. *The Better Housing of the Wage-earning Classes in Rural Districts.*
By Rev. J. O. Bevan, *M.A.*, *F.G.S.*

After a review of the past the writer enlarges upon the tendency of the evils of insanitary dwellings to become permanent, and enforces the necessity of taking instant and active steps to abate such evils. He touches upon certain requisites in the location and building of a house on right principles, and shows how many of these requisites are persistently lacking in ordinary dwellings for the labourers in rural districts, whose health is affected, whose morals are vitiated, and whose wage-earning capacity is lessened in consequence of the state of things universally prevalent. He calculates that six-and-a-half to seven millions of pounds are lost to the labouring and artisan class year by year in England in wages by reason of sickness. Furthermore, he considers the matter in respect of the migration to the towns, which has assumed considerable proportions of late years. He goes on to point out what may be done by voluntary means and educational effort on the part of landlords, medical officers, and clergymen, and proceeds to touch upon the efforts recently made by the Legislature to bring the force of law to bear in such wise as to effect a useful and healthful reformation, to inaugurate a new period, and to mark a new advance alike in national comfort, happiness, and prosperity.

SATURDAY, AUGUST 6.

The following Papers were read:—

1. *Adam Smith and his Relations to recent Economics.* *By* L. L. Price, *M.A.*

There are difficulties in discussing the writings of Adam Smith, and it is not easy to say anything new. Some rumours have been recently current of charges of plagiarism, but these require special knowledge, if they are to be treated satisfactorily, and are easier to advance than refute. It is more agreeable to indicate some of the qualities which seem to have given the 'Wealth of Nations' its unique place in economic literature. First among these should be ranked its literary merits, and these are largely due to the strong motive by which the book is inspired. Adam Smith felt a passion for freedom, which has been ascribed to the circumstances of his age, and considered by some critics to be now out of date. But the argument for liberty has a perpetual application. Adam Smith appeals to the layman as well as the economic expert, and the qualities which attract the one might have been supposed to deter the other. But by writers of almost every school in England he has been regarded as the parent of modern economics. In the generation after him Malthus and Ricardo, differing on method, agreed in owning his teaching. At a later time representatives of the historical school, like Cliffe Leslie, have highly esteemed him, and considered him an employer of the inductive method; and Professor Marshall has traced back to him the beginnings of the theory of measurable motives, and regarded him as largely deductive. Nor is it merely the central theory of value which may be found in germ in the 'Wealth of Nations'; but it is surprising to find how close Adam Smith is to the latest results of inquiry on the laws governing the distribution of wealth—on wages, on profits, and even on rent. His exposition of free trade has been subjected to much able criticism on various grounds, but he seized hold of the most important and enduring arguments. His insistance on the true character and real functions of money is a touchstone to which there are few protectionist arguments that can be brought without destructive results to their validity.

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2. *The Effects of Consumption of Wealth on Distribution.* *By* William Smart, *M.A., Lecturer on Political Economy in Queen Margaret College, Glasgow.*

The most pressing question of economics is that of distribution. Its most hopeful solution seems to be in the direction of distribution according to product, as likely to give an equal rational basis for all kinds of income. Our recognition of the current want of proportion between income and wealth produced is due mostly to Socialist theory; but as this founds it on a superficial theory of value, we have to find another basis for its quite just conclusions. The first problem stated, How is the contribution of each factor to product to be measured, considering that what has to be distributed is not product but value of product? But another problem concerns, not the sharing, but the total value to be shared:—1. Value is not in the producer's hand; while production is going on value is changing. Is it desirable that the wage earner should follow the change? 2. In virtue of the progress of invention and organisation the last comer sets the pace for his trade, reduces prices, and yet maintains wage. If reduced prices sweep away the remuneration of those whose capital is fixed, how can the worker continue to be paid the former wage?

These difficulties suggest, however, that distribution is not altogether dependent on income received, but on the uses to which incomes are put. Consumption of wealth, theoretically in our hands, practically is dictated by the merchant; the importance of this as regards the disposition of social wealth; the true meaning of

consumption as taking wealth out of the world; its six categories, showing how various are the effects on social possibilities; the place of services in consumption. Conclusions:—(1) as to the culpability of luxury; (2) as to the desirableness of non-consuming; (3) as to wise consumption.

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3. *On Copyright and Patents.* *By* Robert A. Macfie.

In the first the writer contends for some valuation by a competent responsible board or referees of the work to be privileged, and a regulation of the remuneration receivable therefrom in the interests of the public, *inter alia* favouring the royalty system of rewarding authors. He is of opinion that the working classes are wronged, and public interests injuriously affected, by the forty-two years of absolute monopoly assured under the present law.

As to the second, patents for inventions, the writer contrasts the present with the originally prevalent ideas on the subject of inventions and the remuneration of first inventors. He would have the value of novelties estimated, and exclusive privileges granted with more circumspection and with due regard to the necessity of using the inventions of different minds in combination, and to the inconsistency of nakedly exposing British manufacturers to only superficially equal competition with their rivals abroad, even the exactions of patentees forming a burden which acts as a favour to foreigners who carry on their business in places such as Holland, where there are no burdens of the kind to be borne.

MONDAY, AUGUST 8.

The following Papers were read:—

1. *The Continuance of the Supply of Wheat from the United States with Profit to the Western Farmers.* *By* Edward Atkinson, *Ph.D., LL.D.*

In 1870 and 1873 the price of wheat in Mark Lane averaged a fraction above 54*s.* per quarter.

Such have been the reductions in the cost of producing wheat in the Western States, 1,200 to 1,500 miles from the seaboard, that the farmer now derives as good a return for his capital and labour at 32*s.* per quarter, or less, as he did in the former period at 54*s.*

The application of the self-binder to the reaper in 1876 removed the only substantial limit to the production of wheat in the United States except the price, as the area now occupied in its production is only 2 per cent. of the area of the country, omitting Alaska.

The Western farmers of the United States have thriven in the face of declining prices and advancing wages; they are not heavily burdened with mortgages, and are creditors rather than debtors.

Official proofs cited in the relation to six typical States, proving that while more than half the farms are free from mortgage, the total incumbrance is less than 25 per cent. on the assessed value of all farms.

The purpose of these investigations is their bearing upon the silver question; this matter is elucidated and the present aspect of that question is stated.

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2. *The Agricultural Position in the United Kingdom.*
By Professor R. Wallace.

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3. *Legislation in America and Elsewhere on behalf of Destitute and Neglected Children.* *By* Rosa M. Barratt.

The object of this paper is to show what great advances almost every country, except England, has made in recent years with regard to legislation on behalf of neglected children.

The Chamber of Deputies in *France* has under consideration very wide-reaching proposals on this subject, of which a part became law in July 1889. Under this law certain associations, or *l'assistance publique*, or private individuals may be appointed guardians of children under sixteen years of age—(*a*) if the parents from destitution or other causes voluntarily give them up; (*b*) of those children whose parents are legally deprived of their control through being criminals or habitual drunkards.

As to *America*. The laws of Michigan as they concern neglected children have been so successful that they have been copied, with but slight differences in detail, by the States of Wisconsin, Minnesota, and Rhode Island. By these laws any ill-treated child under the age of sixteen may be removed from its parents and placed under the protection of public authority. New York, Massachusetts, Maryland, Connecticut, Indiana, California, Colorado, Illinois, and Ontario partially, have also most stringent laws as to neglected children; in most cases the Governments give grants in aid of efforts to rescue them.

In *Italy* and *Germany* also great efforts are now being made to consolidate charitable efforts on behalf of the poor, and to give increased authority and power and State aid to such workers.

Voluntary charitable efforts in order effectually to check the increase of pauperism and crime must have Government aid and protection.

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4. *A Plea for the Study of Railway Economics.* *By* W. M. Acworth.

Railway economics is a recognised subject of instruction with a large literature of its own (*see* 'Economic Journal' for June for list) in other countries. Here the study is non-existent. And yet railways deserve study, both from their pre-eminent financial importance, from the fact that the transportation industry lies at the base of all other industries, and from the extreme difficulty of the problems involved. The position of English railway statistics is at present simply discreditable, and, in the absence of information, the subject has become a happy hunting-ground for the crotchet-monger, and England, which invented railways, has dropped out of sight among the railway experts of the world; is, for instance, practically ignored at the International Railway Congress now meeting at St. Petersburg. Three subjects of immediate practical importance are suggested as requiring special study:—

1. The reduction of passenger fares begun in Hungary, extended to Austria, Holland, France, and expected in Germany ere long. How far does this afford a precedent for England? Reasons are suggested for thinking that Ireland might with great advantage copy the Hungarian example, while in Great Britain such a course is out of the question.

2. The question of goods rates is commonly understood to have been finally settled last session; but there is reason to believe, on the contrary, that it is only just beginning. There is great need for the guidance of trained economists with no personal interest to serve.

3. The construction of new railways, which are urgently needed, has been practically put a stop to by the extravagant standard of construction and working demanded by English public opinion. On the other hand, cheap railways are making very rapid progress in Holland, Belgium, Italy, and elsewhere, and according to the testimony of the Prussian Minister of Commerce, given on moving the third reading of a Light Railway Bill for Prussia, they have proved of inestimable value to those countries. Is it not possible that we in this country had better have inferior railways in remote districts rather than none at all?

TUESDAY, AUGUST 9.

The following Papers and Report were read :—

1. *Illegitimacy in Banffshire.* *By* Wm. Cramond, *A.M., LL.D.*

I. Maps, diagrams, and tables exhibited to show the relative position of Banffshire for the last five years (1887–91): Banffshire, 14·8 per cent. of illegitimacy; Shetland, 3·9; Midlothian, 7·5; Wigtown, 16·6. Percentage of illegitimate births to total births in Scotland for the last thirty-four years, 8 per cent.; Banffshire, 16 per cent. Since 1858 Banffshire has had the highest percentage in Scotland thirteen times; Wigtown, fifteen times. Distribution of the population and other county statistics.

II. Registration districts of the county classified according to percentage of illegitimacy for period 1858–91 (inclusive). One district—Seafield, 7 per cent.—is below the average for Scotland; all the other twenty-three districts are above. Highest, Kirkmichael with 24 per cent. Seven of the eight lowest districts are seaboard parishes with a fishing population. The twelve districts with the highest percentages are all purely rural.

Table showing in parallel columns for each of the twenty years, 1872–91, the percentage of illegitimacy in Scotland, Banffshire, Seafield, Marnoch, and New Byth. New Byth is believed to have the highest percentage in the three kingdoms. It reached 42 per cent. in 1889 (36 legitimate births, 26 illegitimate).

Table showing percentage of each registration district in the county for the five years, 1882–86, and for the five years 1887–91. Result: all town districts show improvement, purely rural districts, as a rule, getting worse. Comparative statistics of births, deaths, and marriages for twenty years in a district with a very low percentage (Seafield) and in a district with a very high percentage (Marnoch).

III. Tables showing the occupations of fathers of illegitimate children—they are mainly farm servants. 'Although the agricultural class does not number one-half of the community by some 1,800 persons, it contributes almost double the number of illegitimate births that all other classes of the community taken together contribute.'

Tables showing the occupations of mothers. Average number of legitimate births in the county for seven years, 1,655; of illegitimate, 319. Of these 319 the mothers of 262 were domestic or farm servants.

IV. The causes are *not* (1) Want of education; (2) poverty or pauperism; (3) excess of female life; (4) one-room houses; (5) race; (6) religion; (7) heredity, &c. Proofs of these assertions.

V. Analysis of 200 opinions given by representative persons in the county as to the causes. The one main cause is want of dwelling-house accommodation on farms for married servants and for servants inclined to marry.

VI. *Remedy.*—Provide cottages proportionate to size of farms, granting compulsory powers to county councils. Table showing illegitimacy was much less in the early part of this century, prior to the system of joining farm to farm and demolishing cottages.

2. *Taxation of Building Land.* *By* Mark Davidson.

The subject of the paper is taxation of building land. It deals with three proposals: (1) the taxation of ground-rents, (2) assessment of unoccupied land capable of yielding ground-rent, and (3) acquisition by the community of the unearned increment of land. The chief question of economic interest concerning the first is whether, according to the present system of rating, ground-rents are taxed for local purposes or not, for no problem is to be met with in regard to the levying or incidence of such an impost. The question is one of assessment, and, according to the method of assessment adopted, rent of ground already pays rates equally with rent of houses. To tax it additionally would be to alter the principle on which rating proceeds, and would tax lands of identical values at different rates.

On the other hand, the second proposal is in keeping with the system of local rating adopted, for vacant land, being excepted from rating, is treated differently from other real property. The third proposal is the most complex; because it is not a matter of taxation, but of the acquisition of property, and the difficulty of the problem consists in the fact that it is desired to appropriate real property without assuming the right to administer it. The unearned increment is an additional value given to land by a certain increase in the demand for it; and the increased demand is caused by certain pecuniary advantages which settlement on the land conveys. In so far, therefore, as the community which causes the demand acquires the unearned increment accruing therefrom, the consequence will be that that community will acquire the advantage over others which formerly augmented the rental paid. The actual economic result, however, is probably indeterminate. In conclusion, the author discusses the possible method whereby the unearned increment could in practice be absorbed by the community.

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3. *Report on the Teaching of Science in Elementary Schools.*
See Reports, p. 368.

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4. *The Methods of Industrial Remuneration.*[1]
By DAVID F. SCHLOSS, *M.A., S.C.L.*

An employee engaged on *time-wage* sells to his employer the labour performed within a given period, irrespective of the amount of this labour; if on *task-wage*, he sells the labour performed within a given period, undertaking to produce within that period a specified output; if on *piece-wage*, he sells a specified amount of labour (the amount necessary for the production of a specified output), irrespective of the period within which this labour is performed. [Note that all forms of the wage-system, whether express and primary reference be made to a time-basis or a result-basis, are alike in effect based on a more or less definite *standard of remuneration, i.e.*, a fixed ratio between time, output, and pay, the price per unit of exertion tending to be the same, under whichever method the operative be employed.] There is also the special method of *progressive wages*, under which the employee, if his labour exhibits a specified degree of efficiency, obtains in addition to his fixed or minimum time-wage or piece-wage a *premium*.

Wages, if paid in respect of the labour performed by a man working 'single-handed' are *individual wages;* if paid in respect of the joint labour of a group, *collective wages*. In addition to *collective task-wage*, *collective piece-wage*, and *collective progressive wages* we find the method of *contract work*, under which the lump sum paid as the price of the work done by the group is apportioned by, first, deducting the time-wages of its subordinate members, and then paying to the leading member or members out of the balance a piece-work remuneration varying in amount inversely with the sum of these time-wages, and directly with the speed maintained by the group; and the method of *co-operative work*, distinguished from all other forms of collective wages by the fact that the price of the work is apportioned, not by the employer, but by the members of the group themselves.

Payment by results, whether piece-wage or progressive wages, applied to the remuneration of the foreman or leader of a group sometimes induces a severity of supervision objected to by the working-classes, who stigmatise as '*the sweating system*' many (though not all) cases in which workpeople, instead of being employed under a time-wage foreman, are employed under a foreman or other superintendent paid by results, or work under a '*sub-contractor*,' *i.e.*, a subordinate employer.

Under *product-sharing*, a system falling into desuetude, the employee is remunerated by a share in the output or its value either in lieu of, or in addition to, wages. Under the semi-co-operative method of *profit-sharing* the employee

[1] The paper is published in *Charity Organisation Review*, October–November 1892.

receives in partial remuneration of his labour and in addition to his ordinary wages a share fixed beforehand in the profits realised by his employer. Under *industrial co-operation* the workers are their own employers, their remuneration consisting, not in wages, but in the entire earnings of the business divided in agreed proportions. Profit-sharing is applicable only in a restricted, co-operation in a very narrow range of cases. But the object of co-operation—the just distribution of the product of industry—may be attained under the non-co-operative wage-system to an extent greater than is frequently supposed.

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5. *The Criminal and the Habitual Offender from an Economic, Statistical, and Social Standpoint.* *By* J. F. Sutherland, *M.D.* (*Edin.*)

The author sets forth *in extenso*, for the first time so far as he is aware, an analysis of the criminal returns, with the object of proving how, under a system of procedure which should have been condemned long ago as antiquated and hurtful, a large and increasing number of offenders (habitual)—for the most part idlers and drunkards—thrive in an industrious community, and not only so, but the ineffectual attempts to reform the individual, and to make him or her *nolens aut volens* a contributor to the national wealth and prosperity, are made at enormous cost from funds provided by the industrious members of society.

The annual bill which the nation pays without murmur for the repression of crime falls little short of 8,000,000*l.*, and the results so far as the 'habitual' is concerned are simply nil. Nay, more, it can be demonstrated that there is every encouragement to continue idle and debauched.

It will be observed that the number of apprehensions, &c., by the police in the United Kingdom and Ireland for offences against the laws which society from time to time has framed for its protection number over a million (1,148,190), or 1 to 33 of the population; England contributing 755,740, or 1 to 39 of the population; Scotland 151,480, or 1 to 26 of the population; and Ireland 240,970, or 1 to 19. This is a black record, but in truth things are not so bad as they look. These enormous totals, be it understood, do not represent so many units of the population who have by choice or by force of circumstances gone under in the struggle. Far from it. What investigation shows is this, that under the system *one individual or unit is responsible for as many as five, ten, twenty, forty, and fifty* apprehensions in the course of a single year. These are the non-producing units whom the writer desires to see deprived of the liberties and opportunities which permit them, without let or hindrance, not merely to offend against a code of decency and morality, but to live lives of idleness at the expense of the industrious taxpayer.

After the million and odd have been examined and sifted they dwindle down to less than a fourth of their original proportions, and these 255,314 have to be looked for and found within the prisons of the country: 137,000 persons are responsible for the 255,314 commitments to prison. Of these the really worthless and idle are few. They are made up of 12,380 felons, &c., and 10,100 habitual (petty) offenders.

In the community there are four well-defined specimens of the *hostes humani generis*. First, the genuine criminal or felon who is only responsible for 2 per cent. of the entire apprehensions, and 36,650 of the same *genus* at large; second, the 'casual' offender, 100,000 or thereby in number. As a rule, the 'casual' is an industrious and productive member of the commonwealth, but occasionally commits follies which bring him or her within the grasp of the law. Third, the 'habituals,' 10,100 in number, Scotland's share being 1,500. These neither toil nor spin, have no settled abode, live among the worst environments, sanitary and otherwise. This is the class fully matured for seclusion from society, upon whose resources they are a constant and heavy drain.

1. Are the results commensurate with the cost?

2. Is there a better and more economic way?

3. Can the idle be made industrious, the debauched sober, and the commonwealth benefited?

The writer puts forward the following remedial proposals:—

1. In the first group, the Felon, &c., the author has no specific to recommend. Compulsory national education, sanitary reform, elevating influences, prison reform, and reform of criminal procedure have done much for this class.

The figures having reference to the petty offenders present disquieting elements. For years there has been such a steady increase as to suggest the inquiry now made.

2. The 'Casuals.'

3. The 'Habituals.' After six convictions for the offences specified within twelve months or less period, or twenty extending over any period, the 'repeater' should be declared an 'habitual,' and should be removed from society for an indefinite period, and placed in a retreat.

Among the 'Habituals' there are three pronounced types requiring differentiation in treatment.

For the worst class, made up of the refractory and incorrigible, there is ample room in some of the all but unutilised poor-houses up and down the country, or in a prison or part of a prison set aside for the purpose. In twenty workhouses, with accommodation for 3,340 inmates, only 893, or 26 per cent., can be found to occupy places, and in other three, with 1,186 places, 568, or 48 per cent.

4. The 'Intermediates.' Cumulative and progressive penalties as sketched in paper.

Section G.—MECHANICAL SCIENCE.

President of the Section—Professor W. Cawthorne Unwin, F.R.S., M.Inst.C.E.

THURSDAY, AUGUST 4.

The President delivered the following Address:—

By what process selection is made of a Sectional President of the British Association is to me unknown. I may confess that it was pleasant to receive the request of the Council to preside at the meetings of Section G, even though much of the pleasure was due to its unexpectedness. I ventured to believe I might accept the honour gratefully, trusting to your kindness to assist me in fulfilling its obligations. Amongst engineers there are many with greater claims than I have to such a position, and who could speak to you from a wider practical experience. Here, in Section G, I think it may be claimed that the profession of engineering owes much to some who from circumstances or natural bias have concerned themselves more with those scientific studies and experimental researches which are useful to the engineer than with the actual carrying on of engineering operations. Here, at so short a distance from the University where Rankine and James Thomson laboured, I may venture to feel proud of being amongst those whose business it has been rather to investigate problems than to execute works.

The year just passed is not one unmemorable in the annals of engineering. By an effort remarkable for its rapidity, and as an example of organisation of labour, the broad gauge system has been extinguished. It has disappeared like some prehistoric mammoth, a large-limbed organism, perfect for its purpose and created in a generous mood, but conquered in the struggle for existence by smaller but more active rivals. If we recognise that the great controversy of fifty years ago has at last been decided against Brunel, at least we ought to remember that the broad gauge system was one only of many original experiments, due to his genius and courage, experiments in every field of engineering, in bridge building, in locomotive design, in ship construction, the successes and failures of which have alike enlarged the knowledge of engineers and helped the progress of engineering.

The past year has seen the completion of the magnificent scheme of water supply for Liverpool, from the Vyrnwy, carried out from 1879 to 1885 by Mr. Hawksley and Mr. Deacon, and since then completed under the direction of the latter engineer. This is one of the largest and most striking of those works of municipal engineering, rendered necessary by the growth of great city communities, and made possible by their wealth and public spirit. For the supply of water to Liverpool the largest artificial lake in Europe has been created in Mid-Wales by the construction across a mountain valley of a dam of cyclopean masonry, itself one of the most remarkable masonry works in the world. The lake contains an available supply of over 12,000 million gallons, its size having been determined, not only to supply forty million gallons daily for the increasing demand of Liverpool, but also to meet the necessity imposed by Parliament that an unpre-

cedentedly large compensation, amounting to ten million gallons daily and fifty million gallons additional on thirty-two days yearly, should be afforded to the Severn. The masonry dam, though a little less in height than some of the French dams, is of greater length. It is nearly double the length of the great dam at Verviers.[1] Although masonry dams were an old expedient of engineers, it is in quite recent times, and chiefly in consequence of the scientific investigations of French engineers, that they have been revived in engineering practice. Since the construction of the Vyrnwy dam another very large dam, the Tansa dam, has been completed in Bombay. This dam has a length of two miles and a height of 118 feet, and it is 100 feet thick at the base. The reservoir will supply 100 million gallons per day. In the United States a still greater work of the same kind has been commenced on the Croton River in connection with the water supply of New York. This dam will have a length of 2,000 feet and a height of 285 feet. Its greatest thickness will be 215 feet. It will be very much the boldest work of its kind.

Returning to the Liverpool supply, the water taken from the lake at the most suitable level into a straining tower provided with very complete hydraulic machinery passes through the Hirnant tunnel, and thence by an aqueduct, partly consisting of rock tunnels, partly of pipes 39 in. to 42 in. in diameter, sixty-eight miles in length, being the longest aqueduct yet constructed. The crossing of the Mersey by an aqueduct tunnel has proved the greatest engineering difficulty to be surmounted. The tunnel has been carried through layers of running sand, gravel, and silt. At first slow progress was made, but later, by the adoption of the Greathead system of shield, with air locks and air-compressing machinery, as much as fifty-seven feet of tunnel were driven and lined in one week. The whole work is now complete, and Liverpool has available an extra supply of very pure water, amounting to forty million gallons daily.

A scheme of water supply for Manchester from Lake Thirlmere in Westmoreland, on an equally large scale, is approaching completion. Birmingham is likely to carry out another work of the same kind. And London, at a greater distance from pure water sources and under greater difficulties from the complexity of existing interests, has come to realise that, within fifty years, a population of 12½ millions will probably have to be provided for. To supply such a population a volume of water is required ten times as great as the whole available supply from Lake Vyrnwy.

Here in Edinburgh one remembers that the birthplace of the steam-engine is near at hand. A century and a quarter ago James Watt made an invention which has profoundly influenced all the conditions of social, national, commercial, and industrial life. It is due to the steam-engine more than to any other single cause that the population in this country has tripled since the beginning of the century, and that we have become dependent on steam-power for fuel, for transport, for manufactures, in many cases for water supply, for sanitation, and for artificial light. From some German statistics it appears that there are probably now in the world, employed in industry, steam-engines exerting forty-nine million horse-power, besides locomotives exerting six million horse-power. Engines in steamships are not included. The steam-engine has become a potent factor in civilisation, because it places at our disposal mechanical energy at a sufficiently low cost, and the efforts of engineers have been steadily directed to diminishing the cost at which steam-power is produced. Members of one great branch of our profession are much concerned in the production of mechanical energy at a sufficiently cheap rate. They require it in very large quantity for transformation into light and for re-transformation into mechanical energy under conditions more convenient than the direct use of steam-power. Perhaps it will not be inappropriate if, in Section G, I first discuss briefly some of the causes which have made the steam-engine inefficient, and the extent to which we are getting to a scientific knowledge of the methods of evading them. I propose, then, to consider some of the methods of economising the cost and increasing the convenience of

[1] The length of the dam from rock to rock is 1,172 feet. Height from lowest part of foundation to parapet of carriage way, 161 feet. Height from bed of river to overflow sill, 84 feet. Thickness of masonry at base, 120 feet.

mechanical power by generating it at central stations and distributing it, and, lastly, how far means of transporting energy are likely to make available cheaper sources of energy than steam-power.

Let us go back for a moment to James Watt. The most distinct feature about the invention of the steam-engine is that it arose out of studies of such questions as the relation of pressure and temperature of steam, the heat absorbed in producing it, and its volume at different pressures.

Armed with this knowledge, Watt was able to determine that the quantity of steam used in a model atmospheric engine was enormously greater than that due to the volume described by the piston. There was waste or loss. To discover the loss was to get on the path of finding a remedy. The separate condenser, by diminishing cylinder condensation, annulled a great part of the loss. So great was Watt's insight into the action of the engine that he was able to leave it so perfect that, except in one respect, little remained for succeeding engine builders, except to perfect the machines for its manufacture, to improve its details, and to adapt it to new purposes. Now it very early became clear that there were two directions of advance which ought to secure greater economy. Simple mechanical indications showed that increased expansion ought to insure increased economy. Thermodynamic considerations indicated that higher pressures, involving a greater temperature range of working, ought to secure greater economy. But in attempting to advance in either of these directions, engineers were more or less disappointed. Some of Watt's engines worked with 5 lb. of coal per indicated horse-power per hour. Many engines with greater pressures and longer expansions have done but little better. The history of steam-engine improvement for a quarter of a century has been an attempt to secure the advantages of high pressures and high ratios of expansion. The difficulty to be overcome has proved to be due to the same cause as the inefficiency of Watt's model engine. The separate condenser diminished, but it did not annul the action of the cylinder wall. The first experiments which really startled thoughtful steam engineers were those made by Mr. Isherwood between 1860 and 1865. Mr. Isherwood showed that in engines such as those then in use in the United States Navy, with the large cylinders and low speeds then prevalent, any expansion of the steam beyond three times led, not to an increased economy, but to an increased consumption of steam. Very little later than this M. Hirn undertook, in 1871-5, his classical researches on the action of the steam in an engine of about 150 indicated horse-power. Experiments of greater accuracy or completeness, or of greater insight into the conditions which were important, have never since been made, and Hirn with his assistants, MM. Hallaner and Dwelshauvers Dery, has determined, once for all, the whole method of a perfect steam-engine trial. M. Hirn was the first to clearly realise that the indicator gives the means of determining the steam present in the cylinder during every period of the cycle of the engine. Consequently, superheating in ordinary cases being out of the question, we have the means of determining the heat present and the heat already converted into work. The heat delivered into the engine is known from boiler measurements, combined with calorimetric tests of the quality of the steam, tests which Hirn was the first to undertake. The balance or heat unaccounted for is, then, a waste or loss due to causes which have to be investigated. Hirn originated a complete method of analysis of an engine test, showing at every stage of the operation the heat accounted for and a balance of heat unaccounted for; and the latter proved to be a very considerable quantity.

Meanwhile theoretical writers, especially Rankine and Clausius, had been perfecting a thermodynamic theory of the steam-engine, based primarily on the remarkable and irrefragable principle of Carnot. The result of Hirn's analysis was to show that these theories, applied to the actual steam-engine, were liable to lead to errors of 50 or 60 per cent., the single false assumption made being that the interaction between the walls of the cylinder and the steam was an action small enough to be negligeable.

In this country Mr. Mair Rumley, following Hirn's method, made a series of experiments on actual engines with great care and accuracy and completeness. All these experiments demonstrated the fact of a large initial condensation of steam on the walls of the cylinder, alike in jacketed and unjacketed engines. This con-

densed steam is re-evaporated partially during expansion, but mainly during exhaust, and serves as a mere carrier of heat from boiler to condenser, in conditions not permitting its utilisation in producing work.

It became clear from Hirn's experiments, if not from the earlier experiments of Isherwood, that for each engine there is a particular ratio of expansion for which the steam expenditure per horse-power is least. Professor Dery has since deduced from them that the practical condition of securing the greatest efficiency is that the steam at release should be nearly dry. In producing that dryness the jacket has an important influence. In spite of much controversy amongst practical engineers about the use of the jacket, it does not appear that any trustworthy experiment has yet been adduced in which there was an actual loss of efficiency due to the jacket. In the older type of comparatively slow engines it is a rule that the greater the jacket condensation, the greater the economy of steam, even when the jacket condensation approaches 20 per cent. of all the steam used. It appears, however, that as the speed of the engine increases, the influence of the jacket diminishes, so that for any engine there is a limit of speed at which the value of the jacket becomes insignificant.

Among steam-engine experiments directed specifically to determine the action of the cylinder walls, those of the late Mr. Willans should be specially mentioned. Mr. Willans' death is to be deplored as a serious loss to the engineering profession. His steam-engine experiments, some of them not yet published, are models of what careful experiments should be. They are graduated experiments designed to indicate the effect of changes in each of the practically variable conditions of working. They showed a much greater variation of steam consumption (from 46 to 18 lb. per indicated horse-power hour) in different conditions of working than, I think, most practical engineers suspected, and this has been made more significant in later experiments, on engines working with less than full load. The first series showed that in full-load trials the compound was superior to the simple engine in practically all the conditions tried, but that the triple was superior to the compound only when certain limits of pressure and speed were passed.

As early as 1878 Prof. Cotterill had shown that the action of a cylinder wall was essentially equivalent to that of a very thin metallic plate, following the temperature of the steam, the exceedingly rapid dissipation of heat from the surface during exhaust especially being due to the evaporation of a film of water initially condensed on its surface. In permanent *régime* the heat received in admission must be equal to that lost after cut off. In certain conditions it appeared that a tendency would arise to accumulate water on the cylinder surfaces, with the effect of increasing in certain cases the energy of heat dissipation. Recently Prof. Cotterill has been able to carry much further the analysis of the complex action of condensation and re-evaporation in the cylinder, and to discriminate in some degree between the action of the metal and the more ambiguous action of the water film. By discarding the less important actions, Prof. Cotterill has found it possible to state a semi-empirical formula for cylinder condensation in certain restricted cases, which very closely agrees with experiments on a wide variety of engines. It is to be hoped that, with the data now accumulating, a considerable practical advance may be made in the clearing up of this complex subject. There are, no doubt, some people who are in the habit of depreciating quantitative investigations of this kind. They are as wise as if they recommended a manufacturer to carry on his business without attending to his account books. Further, the attempt to obtain any clear guidance from experiments on steam-engines has proved a hopeless failure without help from the most careful scientific analysis. There is not a fundamental practical question about the thermal action of the steam-engine, neither the action of jackets or of expansion or of multiple cylinders, as to which contradictory results have not been arrived at, by persons attempting to deduce results from the mass of engine tests without any clear scientific knowledge of the conditions which have affected particular results. In complex questions fundamental principles are essential in disentangling the results. Interpreted by what is already known of thermodynamic actions, there are very few trustworthy engine tests which do not fall into a perfectly intelligible order. There is only one known

method, not now much used, by which the cylinder condensation can be directly combated. Thirty years ago superheating the steam was adopted with very considerable increase of economy. It is likely that it was thought by the inventor of superheating that an advantage would be gained by increasing the temperature range. If so, his theory was probably a mistaken one. For the cooling action of the cylinder is so great that the steam is reduced to saturation temperature before it has time to do work; but the economy due to superheating was unquestionable, and was very remarkable considering how small a quantity of heat is involved in superheating. The heat appears to diminish the cylinder wall action so much as almost to render a jacket unnecessary. The plan of superheating was abandoned from purely practical objections, the superheaters then constructed being dangerous. Recently superheating has been tried again at Mulhouse by M. Meunier, and his experiments are interesting because they are at higher pressures than in the older trials and with a compound engine. It appears that even when the superheater was heated by a separate fire there was an economy of steam of 25 to 30 per cent. and an economy of fuel of 20 to 25 per cent., and four boilers with superheating were as efficient as five without it.

It may be pointed out as a point of some practical importance that if a trustworthy method of superheating could be found, the advantage of the triple over the compound engine would be much diminished. For marine purposes the triple engine is perfectly adapted. But for other purposes it is more costly than the compound engine, and it is less easily arranged to work efficiently with a varying load.

There does not seem much prospect of exceeding the efficiency attained already in the best engines, though but few engines are really as efficient as they might be, and there are still plenty of engines so designed that they are exceedingly uneconomical. The very best engines use only from 12 to 13 lb. of steam per indicated horse-power hour, having an absolute efficiency reckoned on the indicated power of 16 per cent., or, reckoned on the effective power, 13 per cent. The efficiency, including the loss in the boiler, is only about 9 per cent. But there are internal furnace engines of the gas-engine or oil-engine type in which the thermal efficiency is double this.

In his interesting address to this Section in 1878, Mr. Easton expressed the opinion that the question of water-power was one deserving more consideration than it had lately received, and he pointed to the variation of volume of flow of streams as the principal objection to their larger utilisation. Since that time the progress made in systems of transporting and distributing power has given quite a new importance to the question of the utilisation of water-power. There seems to be a probability that in many localities water-power will, before long, be used on a quite unprecedented scale, and under conditions involving so great convenience and economy that it may involve a quite sensible movement of manufacturers towards districts where water-power is available.

If we go back to a period not very distant in the history of the world, to the middle of the last century, we reach the time when textile manufactures began to pass from the condition of purely domestic industries to that of a factory system. The fly-shuttle was introduced in 1750, the spinning-jenny was invented in 1767, and Crompton's machine only began to be generally used in 1787. It was soon found that the new machines were most suitably driven by a rotary motion, and after some attempts to drive them by horses, water-power was generally resorted to. In an interesting pamphlet on the Rise of the Cotton Trade, by John Kennedy, of Ardwick Hall, written in 1815, it is pointed out that the necessity of locating the mills where water-power was available had the disadvantages of taking them away from the places where skilled workmen were found, and from the markets for the manufactured goods. Nevertheless, Mr. Kennedy states that for some time after Arkwright's first mill was built at Cromford all the principal mills were erected near river falls, no other power than water-power having been found practically useful. 'About 1790,' says Mr. Kennedy, 'Mr. Watt's steam-engine began to be understood, and waterfalls became of less value. Instead of carrying the workpeople to the power, it was found preferable to place the power amongst the people.'

The whole tendency of the conditions created by the use of steam-power has been to concentrate the industrial population in large communities, and to restrict manufacturing operations to large factories. Economy in the production of power, economy in superintendence, the convenience of the subdivision of labour, and the costliness of the machines employed, all favoured the growth of large factories. The whole social conditions of manufacturing centres have been profoundly influenced by these two conditions—that coal for raising steam can be easily brought to any place where it is wanted, and that steam-power is more cheaply produced on a large scale than on a small scale. It looks rather, just now, as if facilities for distributing power will to some extent reverse this tendency.

Let me first point out that water-power, where it is available, is so much cheaper and more convenient than steam-power that it has never been quite vanquished by steam-power.

I find, from a report by Mr. Weissenbach, that, in 1876, 70,000 horse-power derived from waterfalls were used in manufacturing in Switzerland. According to a census in 1880, it appears that the total steam and water power employed in manufacturing operations in the United States was 3,400,000 horse-power. Of this, 2,185,000 horse-power, or 64 per cent., was derived from steam, and 1,225,000 horse-power, or 36 per cent., from water. In the manufacture of cotton and woollen goods, of paper and of flour, 760,000 horse-power were obtained from water, and 515,000 horse-power from steam. If statistics could be obtained from other countries, I believe it would be found that a very large amount of water-power is actually made available. The firm of Escher Wyss & Company, of Zurich, have constructed more than 1,800 turbines of an aggregate power of 111,460 horse-power.

With a very limited exception all the water-power at present used is employed in the neighbourhood of the fall where it is generated. If means were available for transporting the power from the site of the fall to localities more convenient for manufactures, there can be no doubt that a much larger amount of water-power would be used, and the relative importance of water and steam power in some countries would probably be reversed. It is because recent developments seem to make such a transport of power possible without excessive cost and without excessive loss that a most remarkable interest has been excited in the question of the utilisation of water-power. Take the case of Switzerland, for instance. At the present time Switzerland is said to pay to other countries 800,000*l.* annually for coal. But the total available water-power of Switzerland is estimated at no less than 582,000 horse-power, of which probably only 80,000 are at present utilised. I found a year ago that nearly every large industrial concern in Switzerland was preparing to make use of water-power, transported a greater or less distance. Besides the great schemes actually carried out at Schaffhausen, Bellegarde, Geneva, and Zurich, where water-power is already utilised on a very large scale, there is a project to develop 10,000 horse-power on the Dranse, near Martigny.

Hence it is easy to see that problems of distribution of power—that is, the transformation of energy into forms easily transportable and easily utilisable—have now a great interest for engineers.

Besides the power required for manufacturing operations, there is a steadily increasing demand for easily available mechanical energy in large towns. For tramways, for lifts, for handling goods, for small industries, for electric lighting, and sometimes for sanitation, power is required. Hitherto steam-engines, or more lately gas-engines, have been used, placed near the work to be done. But this sporadic generation of power is uneconomical and costly, especially when the work is intermittent; the cost of superintendence is large, and the risk of accident considerable. Hence attention is being directed to systems in which the mechanical energy of fuel or falling water is first generated in large central stations, transformed into some form in which it is conveniently transportable and capable of being rendered available by simpler motors than steam-engines.

Just as in great towns it has become necessary to supersede private means of water supply by a municipal supply; just as it has proved convenient to distribute coal-gas for lighting and heating, and to provide a common system of sewerage, so

it will probably be found convenient to have in all large towns some means of obtaining mechanical power in any desired quantity at a price proportionate to the quantity used, and in a form in which it can be rendered available, either directly or by simple motors requiring but little skilled superintendence.

Telodynamic Transmission.—First, then, let me say a few words as to modes of distributing power which it is possible to adopt. In 1850, at Logelbach in Alsace, M. Ferdinand Hirn used a flat steel belt to transmit power directly a distance of eighty metres. Subsequently a wire rope was used on grooved pulleys. This worked so well that a second transmission to a distance of 240 metres was erected. The details of the system were worked out with great care with a view to securing the least cost of construction, the least waste of energy, and the greatest durability of the ropes. So successful did this system of telodynamic transmission prove that within ten years M. Martin Stein, of Mulhouse, had erected 400 transmissions, conveying 4,200 horse-power, and covering a distance of 72,000 metres.

Just at this time a very able and far-seeing manufacturer at Schaffhausen, Herr Moser, had formed a project for reviving the failing industries of the town by utilising part of the water-power of the Rhine: Hirn's system of wire rope transmission rendered this project practicable. The works were commenced in 1863. Three turbines of 750 horse-power were erected on a fall which varies from 12 to 16 feet, created by a weir across the river. From the turbines the power is transmitted by two cables, in one span of 392 feet, across the river. Similar cables distribute the power to factories along the river bank. In 1870 the transmission extended to a distance of 3,400 feet. Power is sold at rates varying from 5*l.* to 6*l.* per horse-power per annum. In 1887 there were twenty-three consumers of power paying a rental of 3,500*l.* per annum for power. The project has been financially successful, and is still working. At Zurich, Freiberg, and Bellegarde there are similar installations, and a large scheme of the same kind has recently been carried out at Gokak in India. Wire-rope transmissions are of great mechanical simplicity, and the loss of power in transmission is exceedingly small. They are extremely suitable for certain cases where a moderate amount of power has to be transmitted a moderate distance to one or to a few factories. On the other hand, they become cumbrous if the amount of power transmitted exceeds 600 or 1,000 horse-power. The wear of the ropes, which only last a year, has proved greater than was expected, and is a source of considerable expense.

The practical introduction of a system of distributing power by *pressure water* is due to Lord Armstrong. Such a system involves a central pumping station, a series of distributing mains, and suitable working motors. From its first introduction the peculiar advantages of this system for driving intermittently working machines, such as lifts, dock machinery, railway cranes, and hauling gear, became obvious. But, with intermittent working machines, there arose the need of an appliance for storing energy during periods of minimum demand and restoring it in periods of maximum demand. The invention of the accumulator by Lord Armstrong made the system of hydraulic transmission a success, and at the same time fixed its character as a system specially adapted for those cases where intermittent work is required to be done. Lord Armstrong's system of hydraulic distribution by water at a pressure of 700 or 800 lb. per square inch, with the use of accumulators for equalising the variations of supply and demand, has now been widely adopted. The most extensive scheme of that kind hitherto executed is the important scheme carried out by the Hydraulic Power Company. Over fifty miles of pressure mains have now been laid in the streets of London. The Falcon Wharf pumping station contains four sets of compound pumping engines, each of 200 horse-power. Two additional pumping stations have now been erected, and 1,500 lifts are worked from the pressure mains. The minimum charge for water is 2*s.* per 1,000 gallons. This rate of charge is economical for such machines as lifts, but it would be extravagant for machines working continuously. It would be equivalent to a charge of nearly 50*l.* per horse-power per year of 3,000 working hours, apart from interest and maintenance of machines.

I shall indicate later on that in some cases where local conditions are favour-

able, where there is cheap water-power, and the possibility of constructing high-level storage reservoirs, then hydraulic transmission can be adopted with success for distributing power for ordinary manufacturing purposes. But neither telodynamic transmission nor hydraulic transmission has proved suitable as methods for the general distribution of motive power from central stations. Distribution by steam and distribution by heated water have both been tried in the United States, but not with very remarkable success. Only two other methods are available—distribution by compressed air and distribution by electricity.

For many years *compressed air* has been used to distribute power in tunnelling and mining operations to considerable distances. It is only recently that it has been used as a general method of distributing power to many consumers. In many installations the machinery has been rough and unscientific, and the waste of energy very considerable. It is through experience gained and improvements carried out in the remarkable system now at work in Paris, and known as the Popp system, that the great advantages of compressed air distribution have been proved. The Paris system has very gradually developed. About 1870 a small compressing station was erected to actuate public and private clocks by intermittent pulses of air conveyed along pipes chiefly laid in the sewers. In 1889 about 8,000 clocks were thus driven. Meanwhile the compressed air had also been applied to drive motors for small industries. The demand for power thus supplied grew so rapidly that a second compressing station was built in the Rue de Saint Fargeau. In 1889 steam air compressors of 2,000 horse-power were at work, and additional compressors were under construction. The pressure at that time was five atmospheres, and the largest air mains were 12 inches in diameter. Ingenious and simple rotary machines were used as air motors for small powers, and for larger powers any ordinary steam-engine was converted into an air motor. Professor Kennedy made tests in 1889, which were communicated to this Association. He found that a motor four miles from the compressing station indicated 10 horse-power for 20 indicated horse-power expended at the compressing station, an efficiency of 50 per cent only. There were then 225 motors worked from the air mains.

Since 1889 more extended investigations have been made by Professor Riedler, of Berlin, and the chief part of the waste of work has been traced to inefficiency of the air compressors. Compound air compressors of much higher efficiency have now been constructed. The plant at the Saint Fargeau station has been increased to 4,000 horse-power. A new station has been erected on the Quai de la Gare, intended ultimately to contain compressors of 24,000 horse-power. Compressors of 10,000 horse-power are already under construction.

Compressed air transmission, whether or not it is the most economical system, is undoubtedly applicable for the distribution of power on a very large scale and to very considerable distances. There is nothing in any of the appliances which is novel or imperfectly understood. The air is used in the consumer's premises in machinery of well-understood types, and old steam engines can be converted into air motors without difficulty and without alteration of existing transmissive machinery in the factories. Not least important, the air can be measured with accuracy enough for practical purposes by simple meters, and charged for in proportion to the power consumed. Air compressors and air motors are not as efficient as dynamos and electric motors, but in one respect distribution by air and electricity are similar. For distances which are not more than a few miles the loss of energy in transmission is small enough to be insignificant.

There is yet one other mode of power distribution which promises to become the most important of all, and which, in the case of transmission to very great distances, if such transmission becomes necessary, has undoubtedly great advantages over every other method.

About *electrical distribution* of power I shall not venture to say much, partly because I am not an electrical expert, partly because it has been lately pretty fully discussed. In the United States there has been an enormous development of electric tramways, which are essentially cases of electric power distribution. In this country we have the South London and some other railways worked electrically. There are others also on the Continent. But electrical power distribution

to private consumers for industrial purposes has not yet made as much progress as might have been expected. Perhaps electrical engineers have been so busy with problems of electric lighting that they have had no time to settle the corresponding problems of power distribution.

No doubt continuous current distribution presents at the moment the fewest difficulties, or, at any rate, involves the fewest comparatively untried expedients. Several continuous current plants for distributing power are in operation, of which perhaps the most interesting is that at Oyonaz, which was described in Section G last year by Professor G. Forbes. There 300 horse-power obtained by turbines is transmitted 8 kilometres at 1,800 volts. It is then let down by motor transformers to a voltage suitable for lighting and driving motors. A number of small workshops are driven, the power being supplied at a fixed rent.

At the Calumet and Hecla mines on Lake Superior, at the Dalmatia mines in California, and some other places, energy derived from turbines is transmitted distances of a mile or two by continuous electric currents, and used in driving mining machinery, and some cases of the use of electrical distribution in mines in this country were mentioned by my predecessor in his Address last year.

At Bradford a few electric motors are being worked from the electric lighting mains. The largest of these is of 20 horse-power. The price at which the electricity is supplied is not given, but I believe the cost is high when reckoned for continuous working. It would seem that it must be so when the electric current is generated by steam-power.

At Schaffhausen an electric transmission has now been constructed alongside of the wire-rope transmission. The power is derived from two turbines, and is transmitted across the Rhine, a distance of 750 yards, at 624 volts. The current drives a spinning-mill, in which the largest motor is 380 horse-power. The power is sold, I believe, at 3*l.* per horse-power of the motors per annum.

Many engineers have now apparently come to the conclusion that alternating currents will be better for power transmission to considerable distances than continuous currents. One interesting alternate current transmission, partly for power, partly for lighting purposes, has been for some time in operation at Genoa.

On the line of the aqueduct bringing water from the Gorzente rivulet three electric stations are being established. The reservoirs are 2,050 feet above Genoa, and as this is a much greater fall than is required for water-supply purposes, part can be used to generate about 1,600 horse-power.

In the first of the power stations erected there are turbines of 450 horse-power driving two dynamos. A second larger station was completed in November. In this there are eight alternate current dynamos of 70 horse-power each. Six alternators are worked in series, transmitting a current of 6,000 volts. The current is transmitted sixteen miles by bare copper wires, 8·5 mm. diameter, placed overhead. The current is used both for lighting and power purposes.

Another method of using alternating currents was adopted in the remarkable experiment at Frankfort last year. In that case energy obtained by turbines at Lauffen was transmitted to Frankfort, a distance of 108 miles, and used for lighting and driving a motor. The current was obtained at low tension, transformed up to a tension of 18,000 to 27,000 volts for transmission, and then transformed down again for distribution. The loss in the conducting wires ranged from 5 horse-power, when the turbines worked at 100 horse-power, to 25 horse-power, when the turbines worked at 200 horse-power. The efficiency of dynamo, two transformers, and line ranged from 68 to 75 per cent.—a remarkably satisfactory result.

There can be little doubt that if efficient and durable transformers can be constructed, they do give a considerable advantage to an alternate current system. To an ordinary engineer it appears also that the system of producing current at low tension in the dynamo, and using it at low tension in the motors, permits the construction of dynamos and motors more mechanically unexceptionable than those working at high voltage.

I have spoken of the growth of a demand for power distributed in a convenient form in towns. The power distribution in London, Manchester, Birmingham,

and Liverpool by pressure water, and that by compressed air in Paris, shows how rapidly, when power is available, a demand for it arises. A striking instance may be found in the small town of Geneva.

In 1871, soon after the completion of the earlier system of low-pressure water supply, Col. Turrettini applied to the municipal council to place a pressure engine on the town mains for driving the factory of the Society for Manufacturing Physical Instruments. The plan proved so convenient that nine years after, in 1880, there were in Geneva 111 water-motors supplied from the low pressure mains, using 34,000,000 cubic feet of water annually, and paying to the municipality nearly 2,000*l.* a year. The cost of the power was not low. It was charged at a rate equivalent to from 36*l.* to 48*l.* per horse-power per year of 3,000 working hours. But even the high price did not prevent the use of power so conveniently obtainable.

Since then a high-pressure water service has been established, the water being pumped by turbines in the Rhone. From this high-pressure service power is supplied more cheaply. On the high-pressure system the cost of the power is about 0·7*d.* per horse-power hour, or 8*l.* per horse-power for 3,000 working hours.

In 1889 the annual income from water sold for power purposes on the low-pressure system was 2,085*l.*, and on the high-pressure system 4,500*l.* On the high-pressure system the receipts in 1889 were increasing at the rate of 880*l.* per year.

In 1889 the motive power distributed, on the high-pressure system alone, amounted to 1,500,000 horse-power hours, there being seventy-nine motors of an aggregate working power of 1,279 horses.

In Zurich there is a quite similar system and power, amounting to 9,000,000 horse-power hours in the year, distributed hydraulically to various consumers, who pay a rental of 1,200*l.* per annum. It will be noted that all this power in Geneva and Zurich is obtained from water which has been pumped, and it is the low cost of the water-power which does the pumping which makes this possible.

But, further, in both Geneva and Zurich the whole of the dynamos supplying electric light are also driven by turbines using pumped water. The convenience of this arises in this way. The fall obtainable in the river in both cases is a small one, and varies. Large turbines are required, and these cannot work at a constant speed. Further, it is expensive to use these large low-pressure turbines to drive directly dynamos which only work with a considerable load for a short portion of the day. The low-pressure turbines in the river are therefore used to pump water to a high-level reservoir, and they work with a constant load all the twenty-four hours.

From the high-level reservoir water is taken as power is required to drive the dynamos, and the turbines driving the dynamos are small high-pressure turbines, working always on a constant fall at a regular speed, and easily adjusted by a governor to a varying load. The system seems a roundabout one, but it is perfectly rational, effective, and economical.

Few persons can have seen Niagara Falls without reflecting on the enormous energy which is there continuously expended, and for any useful purpose wasted. The exceptional constancy of the volume of flow, the invariability of the levels, the depth of the plunge over the escarpment, the solid character of the rocks, all mark out Niagara as an ideally perfect water-power station, while, on the other hand, the remarkable facilities of transport, both by steam navigation on the lakes and by four systems of railway, afford commercial advantages of the highest importance. From a catchment basin of 240,000 square miles, an area greater than that of France, a volume of water amounting to 265,000 cubic feet per second descends from Lake Erie to Lake Ontario, a vertical distance of 326 feet, in 37½ miles.

Supposing the whole stream could be utilised, it would supply 7,000,000 horse-power. This is more than double the total steam and water power at present employed in manufacturing industry in the United States.

Immediately below the Falls the river bends at right angles, and flows through a narrow gorge. The town of Niagara Falls on the American side occupies the table-land in this angle.

The earliest traders who settled near the Falls erected stream mills in the

upper river in 1725 for preparing timber. Later, the Porter family erected factories on the islands in the rapids above the falls. It was not, however, till about thirty years ago that any systematic attempt was made to utilise part of the water-power of the Falls. Then a canal was constructed from Port Day, about three-quarters of a mile above the Falls, to a forebay or head-race along the cliff overlooking the lower river. In 1874 the Cataract Mill was established, taking power from this canal, and other mills were gradually erected till about 6,000 horse-power was utilised. These mills have been exceedingly prosperous, but since the growth of a feeling against the disfigurement of the Falls it has become impossible to extend works of the same kind.

The idea of a method of utilising the Falls, capable of greater development, and free from the objections to the hydraulic canal with mills discharging tail water on the face of the cliff, is due to the late Mr. Thomas Evershed, Division Engineer of the New York State Canals. He proposed to construct head-race canals on unoccupied land some two miles above the Falls. From these the water was to fall through vertical turbine pits into tail-race tunnels, converging into a great main tunnel, discharging into the lower river. Apart from an inappreciable diminution of the volume of flow over the Falls, this plan avoids any disfigurement of the scenery near the Falls, and permits a head of nearly 200 feet to be made available. It is, however, essential to such a plan that work should be undertaken on a very large scale. In 1886 the Niagara Falls Company was incorporated, and obtained options over a considerable area of land, extending from Port Day for two miles along the Niagara River. In 1889 the Cataract Construction Company was formed to mature and carry out the constructional works required.

The present plans contemplate the utilisation of 100,000 effective horse-power. The principal work of construction is a great tunnel 7,250 feet long, which is to form a tail-race to the turbines, starting from land belonging to the company and discharging into the lower river. The tunnel is 19 feet by 21 feet, or 386 square feet in area, inside a brickwork lining 16 inches thick.

The base of the tunnel is 205 feet below the sill of the head gate, and permits a fall of 140 to be rendered available at the turbines. The brickwork of the tunnel is lined for 200 feet from the mouth with cast-iron plates.

The tunnel has been excavated with remarkable rapidity with the aid of drills worked by compressed air.

The main head-race, about 200 feet wide, will run for about 5,000 feet parallel with the river, having entrances from the river at both ends. Near the lower reach the Soo Paper Company is already arranging to utilise 6,000 horse-power, discharging the water from the turbines through a lateral tunnel into the main tunnel. Near this lower reach will also be placed two principal power stations, from which power will be distributed, either electrically or otherwise in ways not yet fully determined. The first turbines to be erected in these power stations will be twin turbines of the outward flow type of 5,000 effective horse-power. These turbines have a vertical shaft for driving dynamos or other machinery placed above ground.

According to Mr. Eversbed's original plans, it was intended to distribute water by surface canals to different power users, each of whom would sink his own turbine pits, connected below by lateral tunnels to the main discharge tunnel. Some of the power at Niagara will undoubtedly be used in this way, and in the case of industries requiring a large amount of power it will be economical to purchase a site and water rights.

Such a plan is, however, not adapted to smaller factories. Obviously for them it would be more economical to develop the power in one or more central stations by turbines of large size under common management. Further, once given the means of distributing power instead of water, an important extension of the project becomes possible.

Besides supplying power to industries which may locate themselves at Niagara, the power may be transmitted to the existing factories in Buffalo and Tonawanda.

Arrangements are already proceeding to transmit 3,000 horse-power to Buffalo, a distance of 18 miles, to work an electric lighting station.

In 1890 Mr. Adams, the President of the Niagara Construction Company, visited Europe to examine systems of power distribution. It was in consequence of this visit that the important modification of the plans of the company involved in the substitution, to a large extent, of a system of power distribution for a system of water distribution came to be adopted. The American engineers were anxious to obtain the best European advice as to the methods best suited to the local conditions. A commission was formed, consisting of Lord Kelvin, Dr. Coleman Sellers, Professor Mascart, and Colonel Turrettini, and an invitation was given to engineers and engineering firms in Europe and America to send in competitive projects for the utilisation of the power at Niagara and its distribution to different consumers at Niagara and in Buffalo by electrical or other means. Many of the plans sent in were worked out with great care and completeness. As to the hydraulic part of the projects there was some approach to general consent as to the arrangements to be adopted, but as to the methods of distributing the power there was an extraordinary diversity.

Generally the commission reported in favour of electrical distribution, with perhaps a partial use of compressed air as an auxiliary method.

Generally also they reported in favour of methods of distribution by continuous currents in preference to alternating currents. Since the date at which the commission reported, the Frankfort-Lauffen experiment has been made, and in the opinion of some electrical engineers a distinct advance has been achieved in the use of alternating currents at high potential.

The company has not yet decided to adopt any plan for the central stations except in a tentative way. One or more turbines of 5,000 horse-power are to be erected, and probably at first this power will be distributed to Buffalo by an alternating current system.

The cost of a steam horse-power at Buffalo is reckoned at £35 per annum. I believe the company will be able to deliver power at from £10 for large amounts and a greater price for small amounts, this price being reckoned for twenty-four hour days.

The new industry of electric lighting has made necessary the provision of large amounts of motive power. Electric traction similarly depends on the supply of motive power. New chemical and metallurgical processes are being introduced which entirely depend for their commercial success on the supply of motive power at a low price.

Niagara is likely to become, not only a seat of large manufacturing operations of familiar types, but also the home of important new industries.

The following Papers were read:—

1. *The World's Columbian Exposition for* 1893. *By* James Dredge, *Member of the Royal British Commission, and* Robert S. McCormick, *American Representative in London of the Columbian Exposition.*

The great size of Jackson Park, which was assigned by the municipality of Chicago as a site for the World's Columbian Exposition of 1893, enabled Messrs. D. H. Burnham and J. W. Root, the engineers and architects of the Chicago Commission, to prepare a general plan of the exhibition buildings, upon the basis of at least 50 per cent. more covered space than was available at the Paris Exhibition of 1889, while at the same time an ample area was left, which the skill of the landscape gardeners, Messrs. Olmstead & Co., has converted into a noble park that forms a suitable setting for the great range of buildings composing the exhibition.

Except for the fact that Jackson Park is six or seven miles from the centre of Chicago, it is an ideal site for a great exhibition; for as it skirts the southern shore of Lake Michigan the waters of that inland sea can be turned to full account, not only to supply the lagoons, canals, and basins, on which so much of the beauty of the park may depend, but it will afford a means of permitting a naval exhibition to be held, which in completeness, variety, and interest will be without a parallel.

Everyone by this time must be familiar with the form of the triangular piece of ground on which the exhibition will be held: it skirts the south-western shore of Lake Michigan and covers an area nearly twice as large as that of Hyde Park. There is thus sufficient space to allow of the construction of many miles of public walks, and also for the erection of a series of great buildings—to say nothing of very numerous pavilions—which will be devoted to different branches of art and industry, and which collectively will cover no less than 150 acres, or about twice as much as the covered area of the Paris Exhibition of 1889.

There are no fewer than eleven main buildings, devoted respectively to Agriculture, Machinery, Manufactures and Liberal Arts, Electricity, Mines and Mining, Transportation, Horticulture, Women's Industry, the Fine Arts, Fisheries, and the Exhibits of the United States Government. Besides these there is also a great monumental building reserved for the Administration. This latter occupies a dominating position at the end of a vast court, around which are grouped five of the principal structures above referred to, and devoted respectively to Agriculture, measuring 500 feet by 800 feet; Machinery, 492 feet by 846 feet; Manufactures and Liberal Arts, 787 feet by 1,687 feet; Electricity, 345 feet by 700 feet; and Mines and Mining, 350 feet by 700 feet. The effective areas of these buildings are further increased by very extensive annexes, especially those devoted to Agriculture, which include several great pavilions for live stock, forestry, dairy farming, and extensive ranges of sheds for the exhibition of cattle. The principal façades of these five buildings just mentioned form the north and south enclosures to the great central court, at the western end of which is the Administration building, while the eastern end is extended into the lake by a pier of large dimensions. In the centre of the court is a basin, which will be enriched by monumental fountains, and which forms a connection between the extensive and ornamental waterways of Jackson Park and Lake Michigan. Each of the principal buildings, so far at all events as architectural effects are concerned, has been designed by a different American architect, all of them selected on account of their eminence in the profession. Certain leading conditions have been observed by them so as to secure harmony in the general effects, both as regards proportions and classic character; in other respects each architect has had an entirely free hand in his designs. The buildings themselves, which are magnificent in dimensions and most elaborate in detail, will thus form exhibits illustrating the development to which the science of architecture has been brought in the United States. As the remaining principal buildings on Jackson Park are more or less independent of one another, greater freedom of design was permitted to the architects, but they are also intended to serve as exhibits contributed by Chicago architects. The Transportation building, 250 feet by 960 feet, is simple in its outline and almost barbaric in the richness of its decoration; the Horticultural building, almost as big as our own Crystal Palace, is, like it, a magnificent example of construction in iron and glass. The Women's building, 196 feet by 386 feet, is the design of a lady architect, and is severely classic in its outline. The Art galleries will undoubtedly be the most beautiful structures that have ever been seen at any exhibition. The leading characteristic of the Fisheries building will be its picturesqueness, and the United States Government is erecting a structure remarkable for its elaborate architectural effect and the beauty of its decoration. There is no room to speak of the many pavilions that will be scattered over the ground; they will include contributions from every State of the Union, from every nation exhibiting, as well as those erected by the numerous exhibitors privileged to occupy buildings for themselves. The most varied and interesting of these will occupy a space of ground projecting from Jackson Park, and which will form practically a street of nations a mile long. The work of the exhibition has now advanced so far that it is within measurable distance of completion, and it will scarcely be doing justice to the Chicago executive to say that in extent, beauty, and completeness it will as far surpass the Paris Exhibition of 1889 as that exhibition eclipsed all its predecessors.

The Administration building, of which the main feature is a dome 120 feet in diameter, rising to a height of 275 feet from the ground, is a beautiful example of boldness in design; in the other buildings, with one exception, there is nothing

unusual in the dimensions or the treatment, from an engineer's point of view. The roofs are neither very great in span nor original in design, the main object having wisely been to cover a vast area in the cheapest and the most expeditious manner consistent with a realisation of the best effects for the special purpose for which each building was intended. Considerable interest, however, attaches itself to the foundations of all the main buildings. In constructing these, the system found most useful for the great permanent buildings of the city of Chicago has been adopted for these temporary structures; that is to say, a system of independent platform foundations, each unit of which distributes, independently of all the others, a safe proportion of the load which has to be supported by the thin bed. This is a peculiarity which the local conditions of the ground render advisable.

The exception above referred to when speaking of the engineering features of the exhibition buildings is found in the great hall devoted to Manufactures and the Liberal Arts: this will have the largest roof that has ever yet been constructed. The building covers an area of over thirty acres, and consists of a central gallery, 387 feet clear span and no less than 210 feet in height: the length of this vast hall is 1,237 feet and the great roof is hipped at each end. It is surrounded with a series of galleries, insignificant by contrast, both as regards height and span. The trusses forming the great roof are of steel, and resemble to some extent, especially as regards size, the somewhat smaller and considerably lower arches of the machinery hall of the Paris Exhibition, which up to the present has surpassed any other structure of the kind.

It will be remembered with what interest engineers of every nation watched the erection of that great roof, which was undoubtedly a triumph of the contractor's skill. The erection of the Liberal Arts building is a work of much greater magnitude, but it is being carried out by simpler means and with greater facility than the Paris machinery hall.

A travelling stage, wide enough to include two trusses and the whole width of the building, is employed. On this staging are two towers, framed in timber, higher than the roof. The erection of the trusses is carried on from the ground and from the staging to a height of about 100 feet, that is to say, to the level of the main platform of the stage. The upper halves of each pair of trusses are put together upon this platform, and when the lower portions are completed and connected by the longitudinal bracing, the inner members of the upper and lower sections are connected by means of pins, so as to form hinged joints. By means of powerful hoisting apparatus, worked from the floor of the stage, the upper halves are then hoisted to their final position, turning on the hinges. When fully raised the central joint is made good, the outer members of the upper and lower halves are rigidly connected, the hinges are removed, and the permanent joints are completed by riveting. In this way the work is rapidly carried on, and it is expected that the building will be ready for the great inaugural celebration in October next.

2. *The Application of Destructors, especially to the Electric Lighting of Edinburgh.* *By* Professor G. Forbes, *F.R.S., F.R.S.E.*

3. *The Disposal of Refuse.*[1] *By* G. Watson.

1. Introduction.—*The Present Position of the Question.*—The waste products chiefly dealt with are those at present coming under the administration of local authorities, comprising ashbin refuse, and market garbage, fish, and other offal, street sweepings, excremental matter, and manufacturers' refuse, the latter being a term substituted for 'trade refuse' in order to discriminate between shop and market refuse and the waste products of manufacture.

The methods of disposal now generally adopted are, in most instances, incomplete, wasteful, and injurious to the public health. They may be briefly classified as follows:—

[1] Published *in extenso* in *Engineering* for Sept. 16 and 30, 1892.

Ashbin Refuse, Market Garbage, Fish, and other Offal.

Method 1. Putrefaction.—In this process the refuse is dumped on vacant ground, often in the neighbourhood of inhabited houses.

Method 2. Utilisation.—(*a*) Sorting is carried on only to a very limited extent. Reasons are given why it is not likely to come into general use. (*b*) Manure manufacture, as at present pursued in some places, is highly objectionable from a sanitary point of view.

Method 3. Combustion.—It is easy to burn ashbin refuse, by means of arrangements the most simple or the most complete, from a heaped fire in the open air up to an elaborate 'destructor,' involving heavy capital outlay; but it is by no means easy to burn it without any smoke, smell, or noxious fumes being given off. However, the system of burning is now carried on in many places, and in some very satisfactorily, and this is the process to be recommended.

Method 4. Sending to Sea.—This arrangement, which is, of course, only practicable for seaboard towns, is not altogether unobjectionable, as a considerable portion of the refuse floats and is sure to be washed ashore. It is also said to interfere seriously with fishing, as the floating articles get into the nets. In addition, it is essential that the refuse should be taken right out to sea, and this is impracticable in stormy weather, when the system breaks down, causing great inconvenience.

Street Sweepings.

These contain sufficient horse-droppings to be saleable as manure in most cases, though their value is largely affected by the nature of the road material and the quantity of mineral dust contained. They are generally sold for manure, sometimes dumped or tipped, and they may be readily burned.

Excrement.

The use of the public sewers to convey a mixture of domestic sewage and liquid manufacturers' refuse, diluted with a goodly quantity of town's water, and in many cases with surface water from the streets, is the system now generally in favour with sanitary authorities for 'getting rid of' the most dangerous class of refuse. Its ultimate disposal is, in the great majority of cases, not fully provided for, and in many not at all. It is often turned into the nearest water-course, intercepting sewers being provided for carrying it to a point below the town producing it.

Manufacturers' refuse has no business at all in the public sewers, and the producers should be made to dispose of it themselves. The existing laws are sufficient to compel them to purify the effluent before passing it into any water-course. The sanitary objections to the use of sewers as a means of conveyance are very serious, and some of them may be indicated by the mention of the terms 'sewer gas,' 'alternately wet and dry surfaces,' 'leakage.' It is also costly as compared with other systems. Filtration through sand and through fibrous material, by pressure and precipitation, by chemical and mechanical processes, are systems more or less imperfectly adopted by municipal authorities for dealing with liquid refuse, and they leave a large residue in the form of sludge which is, in some places, simply deposited on the ground in heaps or sloughs. At Ealing sewage sludge is being burnt in the destructor very successfully, and this is the proper method of disposal. The authorities of London now barge it out to sea in what is known as the 'Sludge Fleet,' and the amount of black mud stirred up by the passage of a large vessel to or from the Port of London is said to be less than formerly in consequence. It remains to be seen whether the enormous dredging

operations hitherto carried on in the docks and the river will be rendered unnecessary by the adoption of the present system.

Intermittent downward filtration, irrigation, and Webster's electrical precipitation process followed by combustion are final and complete methods of disposal of sewage, while those systems which aim at producing manure may be considered as complete when a market can be found for the product.

Collection from house to house, either on the pail system or on the privy system, is still largely practised, and is in many respects strongly to be recommended, particularly in that it provides the most direct means of conveying the noxious material to the destructors.

Manufacturers' Refuse.

The liquid waste products of manufacturers are rarely dealt with by those who produce them. They are disposed of, as described above, by being turned into the public sewers, which are maintained by rates pressing equally on those who turn in an unlimited amount of liquid refuse and those who produce none. For the disposal of solid refuse manufacturers usually have to pay the local authority in cases where they do not themselves dump it on vacant ground.

2. *Outline of a Scheme for the Solution of the Problem.*—The paper pleads that a systematic and comprehensive system should be elaborated and approved by the leading sanitary engineers, and it sets forth an outline of the scheme by which each class of refuse should be made to assist in the final disposing of the other. Manufacturers' refuse alone is excluded, as it belongs distinctly to the province of the private individual, and not to that of the local authority. Its composition is so varied and its treatment so difficult as to interfere with any scheme proposed for the treatment of towns' refuse. The mixture together of all kinds of waste products from manufactures and the mixture of the mixture with sewage matter often render the ultimate treatment well-nigh impossible. A scheme is, however, indicated by which each manufacturer may use his solid refuse to assist him in disposing of his liquid refuse.

3. *Destructors.*—Destruction by fire is the method recommended for the final disposal of all refuse. An account of the development of this system precedes a short description of each of the furnaces tried in this country or abroad which have received any considerable share of public attention. A fuller description of each of the principal furnaces at present in use in this country follows.

High temperatures are recommended as insuring (with proper arrangements) thorough 'cremation' of the fumes, and also rendering available an immense power from the burning of ashbin refuse, market garbage, fish, and other offal, street sweepings, privy and pail excrement, and sewage sludge (when not mixed with liquid manufacturers' refuse, which is said to be often incombustible). Hitherto it has been generally believed that one ton of ashbin refuse, when burned, gives off heat equivalent to 1·2 I.H.P. for twenty-four hours. That is equivalent to about 6 I.H.P. per cell or furnace of the destructor from which the figures were obtained. The author has proved by recent experiments that burning in the Horsfall destructor at Oldham one ton of mixed refuse (of which the proportions were found by observations extending over eleven weeks to be approximately—ashbin refuse, 95 per cent.; fish offal, 3 per cent.; market garbage, 1 per cent.; street sweepings, 1 per cent.) will convert 328 gallons of water at 67° F. to steam at 70 lb. pressure per square inch. Of this 150 gallons are at present used in promoting combustion (by steam jets), so that from each ton of refuse burnt there is available, say, 1,780 lb. of steam at 70 lb. pressure, which is equivalent to 89 I.H.P. for one hour, or 3·75 I.H.P. for twenty-four hours, as against 1·2 (the generally accepted figure), or over three times as much. It is equivalent to nearly 15 I.H.P. per cell or furnace. If the power were valued at 1*d.* per I.H.P. per hour, which is less than is now the cost at some first-class electric-lighting stations, there is a value of 5*s.* per ton burnt to put against the cost of burning. At Oldham this is 1*s.* 10*d.*, without counting any returns from sale of mortar, &c., and including a charge of 7 per cent. (or 6*d.* per ton net) for interest on capital outlay, repairs, and depreciation, in addition to wages and gas and water rates, and in fact all charges. It does not of course include the cost of collection and cartage, which

may be taken at, say, 2*s.* per ton. Then we have 1*s.* 2*d.* per ton as the net value of the refuse when burnt on this system. A rough outline scheme is described for the burning of London sludge at Barking and Crossness when mixed with ashbin refuse barged down by steam power.

Sites for destructors in special reference to areas of cartage and population are dealt with, and also a calculation is given showing how the refuse of any community is sufficient to provide it with electric light at no extra cost beyond that now involved in refuse disposal. Village refuse is also treated briefly, and united action of sanitary engineers to bring about the general adoption of the combustion system is urged.

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4. *The Absorption and Filtration of Sewage on Sandy and other Soils.*
By Richard F. Grantham, *M.Inst.C.E., F.G.S.*

The author refers to the remarkable results of the experiments conducted for the last two years at St. Lawrence by the Massachusetts Board of Health upon the filtration of sewage.

The results are compared with instances of sewage farming upon sandy soils.

The examples of sewage irrigation at Edinburgh, Dantzig, and Berlin are described, and the effect upon the sandy soil in each case, as well as the average quantity of sewage treated per acre per day, is alluded to.

The particulars of the filter tanks constructed and the materials used by the Massachusetts Board in their experiments are stated, and a table is given to show the quantities treated and the effect upon the nitrogenous matter.

The tanks were 6 feet deep, built water-tight; 17 feet 4 inches in diameter at the top and 16 feet 8 inches at the bottom. Two-inch drain-pipes and a thickness of a foot of gravel and sand, decreasing in coarseness upwards, were laid and spread at the bottom. Above this layers of sand and of gravel and other materials were placed in several tanks. The sewage was delivered on to the surface of the filters intermittently.

The volumes of sewage dealt with in sewage farms are contrasted with the quantities experimented upon, and Dr. Frankland's experiments for the Rivers Pollution Commissioners are shown to corroborate the results of the Massachusetts Board's investigations as regards the quantities and degree of purification.

The action of the filters is shown to be not merely straining the sewage, but in consuming and destroying the organic impurities, and this action is due to the presence in it of organisms which require a supply of oxygen for their existence and multiplication. The interstices in the sand and gravel afford air-spaces for these organisms to multiply; but top soil and mould retain so much moisture that, although the bacteria are filtered out, a large percentage of albuminoid ammonia is left in the effluent.

From the quantity of sewage disposed of on the Berlin sewage farm per acre and from that ordinarily absorbed by intermittent downward filtration are calculated the areas of land that according to the same ratios would be required for the disposal of the London sewage, and these are compared with the space required for the volumes according to the ratio shown by the experiments.

It is suggested that there would be no difficulty, from the nature of the formation of the Maplin and Foulness Sands, in reclaiming and underdraining them and laying them out for filtration areas.

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5. *Shield Tunnelling in Loose Ground under Water Pressure.*[1]
By G. F. Deacon.—See p. 532.

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6. *Proposed Forth and Clyde Ship Canal.*
By David A. Stevenson, *B.Sc., F.R.S.E., M.Inst.C.E.*

The route that has been proposed by Messrs. D. and T. Stevenson, civil engineers, Edinburgh, passes up the valley of the Forth from Grangemouth by

[1] Ordered to be printed *in extenso*.

Alloa and Stirling to Loch Lomond, the surface of which is only 22 feet above the mean level of the sea; thence across the narrow neck of land at Tarbet to Loch Long.

The length of the canal from the Forth to Loch Long is 30 miles, the proposed depth 30 feet, and the width at bottom 72 feet. The locks, of which there are only two—one at each end—will be capable of passing the largest ships afloat—or about 600 feet in length and 80 feet wide, with smaller locks alongside for small craft.

There are no serious engineering difficulties to be overcome. The depth of cutting does not average 50 feet, and is principally in soft materials. The tunnel which it is proposed to construct through the high grounds near Loch Lomond is a large one, namely, $2\frac{1}{4}$ miles in length, with 150 feet headway: it, however, can be made an open cutting if thought desirable.

For the supply of water to the locks Loch Lomond affords an ample reservoir, for it is the summit level of the canal, and has a gathering ground of 21,000 acres.

By this canal vessels from the Clyde to ports on the East Coast of Scotland would save a distance of 529 to 238 miles, while from the Forth to ports on the West Coast of Scotland, South-west of England, Ireland, America, and the Mediterranean, the distances saved would be from 487 to 140 miles.

From Tyne ports to the St. Lawrence River the distance saved would be 150 miles. From West of Britain to North-east of Ireland, and to middle western parts of the Continent, the distance saved would be 377 to 98 miles.

The traffic which would benefit by this canal, an examination of the Returns of Shipping shows, would amount annually to at least 9,000,000 tons.

The estimated cost of the undertaking is 8,000,000*l.* Since the above scheme was put forward a project has been set on foot to make a ship canal on what has been styled the 'direct route' from Grangemouth across the high table-land, over which the present barge canal goes to Yoker on the Clyde.

The objections to this 'direct route' are that, as designed, it will not admit the largest class of vessels now afloat; it necessitates having twelve locks; the time of passage through it will be $11\frac{3}{4}$ hours, as against $8\frac{1}{2}$ by the Loch Lomond route; it will be difficult, or impossible, to obtain a sufficient supply of water for the locks; it debouches above Greenock into a narrow part of the Clyde already crowded; it cannot be entered or left at low water, hence delays; and it will be more expensive to construct.

FRIDAY, AUGUST 5.

The following Papers were read:—

1. *An Automatic Railway for the Carriage of Packages.*
By DAVID CUNNINGHAM, *M.Inst.C.E., F.R.S.E.*

This system of carriage is novel. It is specially economical, as it dispenses with the employment of manual labour in the loading, running, or discharging of the carriages, the whole work being performed by a fixed engine. This engine may drive several lines of a system simultaneously, as is at present done in coal mines. The engine may work the lines through the agency of the endless wire rope system of haulage or of electricity. The author has constructed three different sets of apparatus. The full-size set has been employed experimentally to deal with bales containing each nine cubic feet and weighing 400 lb. weight. The smallest size is that of the model, 20 feet by 10 feet, shown at work.

The system was designed in order to supply a felt want in the distribution of cargoes over an extended floor space. The author submits that it promises assistance in the carriage of packages generally.

The machinery may be fully employed, as there are no railway sidings or stations. The trains run continuously, and take on and discharge their loads while they run. They may take on loads at about six different places, each of

which is independent of the other. They may also discharge their loads at as many places, and these discharging places may be altered at any moment as required.

The trains always run in the same direction, as the lines are continuous curved loops, and they may succeed each other as closely as may be necessary to accommodate the traffic. The system is elastic, and is capable of indefinite extension and of the application of extended automatic appliances. Much complexity of work may be done by a moderate application of power.

It is submitted that the system (which is patent) is competent to produce great convenience and economy in the carriage of packages.

Explanation of the Model.

The model exhibited represents a new system of carriage, which has been invented so as to convey packages in the most economical manner. It has been constructed to show how the system works. No men, boys, or horses are required in the loading, running, or discharging of the trains.

The apparatus exhibited may have six loading and any convenient number of discharging places; but by additional automatic means the system may be indefinitely extended, so that packages may be carried between any desired number of points without failure or confusion.

The loading places may, in general, be fixed and not movable, as in the model, the arrangement represented being that intended for the discharge of cargoes and to suit the hatchways of vessels.

2. *On Electric Locomotives.* *By* Alexander Siemens.

The communication describes the tests made in active work of two electric locomotives supplied by Messrs. Siemens Brothers & Co. to the City and South London Railway. Each locomotive carries two electric motors, together capable of giving 100-brake horse-power; the armatures are wound directly on the axles, so as to do away with all gearing, a plan suggested by the late Sir Wm. Siemens.

The tests were made by simultaneous readings of speed, ampères and volts on the locomotives, and of ampères and volts on the station dynamos; the results are plotted on a series of curves, the mean values of which are summarised in the accompanying table:—

—	Watt Minutes	Ampère Minutes	Total time, including stops	Mean Volts	Mean Ampères	Average running speed, Miles per hour, exclusive of stops
			Min. Sec.			
Stockwell to City, Loco. No. 15, First Journey	322,660	768·65	14 40	419·7	52·41	13·05
" " " " Second "	291,995	689·33	14 16	423·6	48·34	13·27
" " " No. 16, First "	317,640	733·32	14 40	433·2	50·00	13·29
" " " " Second "	315,660	751·32	14 50	420·15	50·60	13·41
Mean	311,988	735·65	14 36	424·16	50·33	13·25
City to Stockwell, Loco. No. 15, First Journey	323,665	766·05	15 30	422·5	49·42	12·19
" " " " Second "	312,995	737·98	15 26	424·1	47·83	12·58
" " " No. 16, First "	305,320	717·99	15 8	425·2	47·46	13·21
" " " " Second "	321,660	749·31	14 56	429·25	50·19	12·83
Mean	315,910	742·83	15 15	425·26	48·72	12·7
Final Mean	313,949	739·24	14 55	424·71	49·52	12·97

3. *The Utilisation of the Energy of Flowing Water. Description of the Purdon-Walters Motor.* *By* Messrs. PURDON *and* WALTERS, *Westminster.*

The motor, which was illustrated by the cartoons exhibited, is designed to convert the energy of flowing water into mechanical power for the purpose of driving electric, pumping, grinding, and other plant.

The machinery of the motor is carried on a pontoon, below which is a lower deck or platform attached to it by uprights. When at work the motor is moored at right angles to the direction of the current, and adjusts itself automatically to the varying levels of flood or tide. The lower platform covers in the moving parts and provides for the motor taking the ground without damage in shallow water, and even being worked in that condition.

The mechanism acted upon by the water consists of blades fixed at even intervals to an endless chain passing over two vertical end wheels, the links of the chain gearing with flat surfaces provided on the wheels. The bearings for the wheel shafts are placed at such a level on the pontoon that half the chain and blades, controlled by fixed guiding rollers, are submerged in the water, while the other half are suspended in the air.

The back portion of the pontoon is constructed with a watertight deck interposed between the end wheels and the upper and lower parts of the chain, so that when motion is imparted to the chain the blades which are submerged have a clear passage through the water between the lower platform and the pontoon, and return in the air above it. The remaining portion of the pontoon for carrying the gearing and machinery to be driven is in the form of an open barge, covered with light shedding where required and boarded up fore and aft, outside the end wheels, from the lower platform, to protect the blades in the water and to permit of the motor being towed.

The space between the pontoon and lower platform through which the current has to pass from the front of the motor to the blades at the back is in the form of a bell mouth, contracted laterally by means of curved wing vanes placed at each end, and vertically by the inclination of the bottom of the pontoon and the lower platform.

In this space the current is diverted into the line of action of the blades, at right angles to the stream, by means of curved guide vanes; and the blades are also curved to receive the pressure and allow of a free escape of the water into the open stream beyond. The whole arrangement is in fact that of the well-known turbine rod.

The bell mouth has the effect of concentrating the energy of a large sectional area of stream at a higher velocity than its natural flow on a comparatively small blade area, the advantage obtained being that the weight of the moving chain and consequent friction is considerably reduced, and the speed of the chain increased.

The action of the machinery impelled by the current is as follows:—

The current impinging on the blades forces those in the water forward with the chain which revolves the end wheels and carries round the blades each in turn, to be submerged and acted upon by the water. One of the end wheels is provided with spur gearing revolving a second motion shaft, from which any higher speed can be obtained by the employment of pulleys and belting.

The energy of a stream varies as the cube of the velocity, and may be expressed by the formula

$$\tfrac{1}{2}\frac{G}{g}\,\Omega\, v^3 = \text{ft. lbs. per second},$$

where G = weight of 1 cubic foot of water.
g = acceleration of gravity.
Ω = sectional area of the stream in feet.
v = velocity of stream in feet per second.

Assuming a pontoon 40 feet long with a sectional area of 151·6 square feet, where the water enters the bell mouth opening, and that the motor shows an

efficiency of 25 per cent., which it is fully expected, from results obtained from an experimental machine moored in the tidewayof the Thames, will be the case, the theoretical horse-power of the stream and that developed by the motor at various velocities would be approximately as under :—

Velocity of Stream		Horse-power of Stream	Horse-power of a machine at 25 per cent. efficiency
in Miles per hour	Feet per second		
1	1·467	0·84	—
2	2·933	6·74	1·68
3	4·4	22·75	5·68
4	5·867	53·94	13·48
5	7·333	105·29	26·32
6	8·8	182·02	45·50

It is obvious from this table that the cost per horse-power depends almost entirely upon the velocity of the current, as the capital outlay, attendance, &c., would be nearly constant. It should also be observed that where considerable power is required the motors can be placed in series at near intervals, and the cost of attendance further reduced.

In deciding whether any particular stream or estuary is suitable for the use of this motor with advantage, as compared with heat engines, it should be remarked that most available figures referring to the working cost of these engines are based upon a day of ten hours, whereas the water motor can be worked with very little attention, even in a tideway, for a greater number of hours, and in a river perpetually.

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4. *On the Extended Use of the Principle of the Hydraulic Ram.* *By* H. D. Pearsall, *Assoc.Mem.Inst.C.E.*

The hydraulic ram is a machine of extreme simplicity which enables the power of a fall of water to be used directly to raise water to any desired height, and it is the only known means of doing this directly, all other means being more or less roundabout and complicated, being a combination of at least two machines, involving a double transformation of power. This simple machine has therefore many very great advantages over any alternative methods, but, notwithstanding this, we find that one hundred years after its invention the older methods are still in use where the quantity of water dealt with is large.

The author investigates the reason of this, and shows that it is chiefly due to an imperfect realisation of the principle of the machine. The paper also gives an account of an investigation of the hydraulic ram by the author and of some engines constructed in accordance with this investigation, which prove that engines on the principle of the hydraulic ram may be advantageously used for the largest water powers, such as waterworks for town supply, irrigation, &c. Similar engines are also remarkably serviceable in compressing air, giving in this case results so far exceeding any hitherto obtained that they vitally affect the important question of transmission of power to a distance.

The ordinary hydraulic ram, as designed by Montgolfier and as still made, is then described.

The violence which accompanies the action of these machines is the first and most obvious reason against their application to large quantities of water, and has given currency to the idea, which the author found to be prevalent, that, as commonly stated, such machines 'acted by a blow.'

This is shown to be a mistake by reference to the elementary dynamic law that any body in motion can be stopped by any resistance, however small, if it continues to act through sufficient distance; from which it follows that the proper action is not 'by a blow,' but by a continued motion of the water against a steady resistance.

The actual causes of the violence which is admitted to occur are then shown to be partly internal, due to avoidable errors in construction, and partly and principally to the concussion of the waste valve in closing at a high speed.

The author then mentions the attempts made by various inventors to diminish this violence by cushioning the blow of the valve, which, while partially successful in their immediate object, result at the same time in impairing the efficiency of the machine, and shows that the explanation sometimes given of this result—viz., that it prevents the instantaneous action imagined to be necessary—is untenable. The true reason of the observed effect is shown to be merely that the slowness of shutting produced by cushioning chokes the flow, and, this being so, a method is at once suggested of shutting slowly without choking the flow, and consequently without impairing the efficiency of the machine.

It having been thus shown that all existing causes of violence are removable, it does not appear that there is any other reason to prevent the extended use of this principle, and in some respects it is much more suitable for use on a large scale than on a small, notably on account of the smaller coefficient of friction in large pipes.

A large engine was constructed to prove the above ideas in practice and discover any unforeseen practical difficulties. The proportions of this engine were deduced from theoretical considerations, discarding the empirical rules formerly in use, as it was found that the theory of the machine indicated the advantage of proportions differing from these. It was also evident that the periods of time during which the main valve was open and shut would be of great importance, and the most suitable times were therefore determined and machinery designed to give the valve exactly this motion. Very much higher velocities were also used in the flow-pipe than had hitherto been used, with the effect of greatly increasing the power of a machine of given size.

The first engine made on this basis was successful, and three others have since been made differing in some practical details. The principal features of these engines are the use of an annular slide valve for the waste valve, moved by a cam in order to obtain exactly the motion required and bring the valve to its seat without any impact, the gradual shutting of this valve being prevented from checking the momentum of the water by the provision of a space into which some of the water flows during the shutting of the valve. This space or antechamber is emptied of water during the opening of the main valve, being provided with an air-valve which admits air at that time, and allows the air to escape as the chamber fills with water.

Precisely similar engines have been also used to compress air, the air being compressed in a chamber similar to the antechamber spoken of above, and its quantity being capable of exact regulation by placing the air-valve in a tube, the depth of which below the roof of the chamber is regulated by a screw.

The general results obtained from these engines are—

1. Entire absence of violence as predicted. An indicator diagram of the internal pressure exhibited further shows this.

2. Very high efficiency, amounting to over 70 per cent. when pumping water, and over 80 when compressing air.

3. That the construction is simple and much less costly than the ancient method, and the management of the engines is easy and the wear slight.

4. Evidence that a similar construction is equally feasible for engines having flow-pipes 3 feet or 4 feet diameter.

In short, it has been established as a fact of actual experience that the simple and useful principle of the hydraulic ram may safely and very advantageously be extended to nearly all cases where water-power is used for pumping or for compressing air, and that there is no need at all to continue in future the use of the antiquated indirect methods, but there are very strong reasons for not doing so.

The author further mentions the result of recent experience in using still higher velocities in the flow-pipe with a view to still further increasing the power of engines of a given size. Velocities eight times as great as used in ordinary

rams have been already employed, and the author expects to employ even greater velocities in future.

The great aid supplied by these machines to the problem of transmission of power is then pointed out. The incidental advantages of using compressed air for this purpose are great, but the practical objection hitherto has been the loss of power incurred in compressing air. As this loss is by the use of the above method almost entirely eliminated, this method of transmitting power will, it is believed, compare favourably with any known method. The reason for the very great efficiency obtained in compressing air (besides simplicity of the apparatus) is that it is accomplished with hardly any heating, because the air during compression (1) is surrounded by and is in contact with cold water in very large quantities; (2) is compressed in a chamber which is washed inside and out at every stroke by large quantities of cold water; and (3) metal surfaces similarly cooled can be added in the midst of the air to any desired extent.

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5. *On a New Form of Windmill.* *By* Professor James Blyth, *M.A.*, *Glasgow and West of Scotland Technical College.*

At the York meeting of the British Association Sir William Thomson suggested the construction of cheap windmills to run dynamos for charging accumulators; but, as far as I know, no practical trial was made till the summer of 1887, when I erected my first electric windmill in the village of Marykirk in Kincardineshire. At that time I procured a set of thirteen accumulators, and constructed a windmill of the old English type, having four arms or whips and canvas sails. I also tried various forms of wind-wheel of the American type, and all these I found to answer very well so long as the wind had a moderate speed, but, like all other experimenters with windmills, I soon found that they had either to be made self-reefing or stopped altogether when a breeze came. This is obviously very unsatisfactory, as the best of the wind for storage purposes is lost; and hence this problem presented itself—how to construct a windmill that would satisfy the following requisites:—

1. It must be always ready to go.
2. It must go without attendance for lengthened periods.
3. It must go through the wildest gale, and be able to take full advantage of it.

A possible solution of the problem is presented in the Robinson Anemometer, which consists of four hemispherical cups attached to four arms and moving in a horizontal plane about a vertical axis. From the theory of this instrument, which is only, however, approximate, it appears that, whatever may be the speed of the wind, the speed of the cups attained a certain terminal value, and that the couple due to the wind-pressure was exactly equal to that produced by the resistance of the motion through the air and the friction on the bearing. It immediately follows that a large machine made on this principle is likely to have the same property, and hence could be allowed to run without danger even in the strongest breeze, and when doing no work.

Last summer I erected a machine of this kind, which has been considerably improved within the past three months. The cups are replaced by semi-cylindrical boxes attached to four strong arms, each about 26 feet long. Two boxes are placed on each arm with a narrow gap between. The diameter of the outer box is 6 feet and its height 10 feet, while the diameter of the inner box is 3 feet, and its height 10 feet. The arms are fixed in metal sockets, which are attached to a strong vertical shaft made of round iron five inches in diameter. The lower end of the shaft carries a massive pit wheel which actuates a train of gearing, and drives a fly-wheel 6 feet in diameter with the requisite speed for a dynamo, connected with it by a belt in the ordinary way. This machine works very satisfactorily, and is at present being used to charge thirteen new E.P.S. cells. With a good wind I reckon that it gives about four horse-power. I have also tested it in a strong gale by allowing it to run with no load, and the result was perfectly satisfactory, as a safe terminal speed was attained and all racing avoided.

Hence I think that electrical windmills, at least for small installations, are likely to assume this form, as they require little or no attention. It is obvious, however, that mills of great size and strength of this form may be constructed, and, if necessary, several could be placed in any well-exposed position, each having its own dynamo and set of accumulators. Regarding the electrical connections, only a word is necessary. The only thing needed is that the circuit be broken when the dynamo is running at less than the storing speed. This is easily managed by having a governor attached to the dynamo shaft which makes and breaks contact in a mercury pool at the required speed. I have also tried a form of governor which throws a greater or less number of cells into the charging circuit as the wind varies, and in this way the machine is always doing some work.

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6. *Flexible Metallic Tubing.* *By* GILBERT R. REDGRAVE, *Assoc.Inst.C.E.*

The author states that numerous efforts have been made in recent times to produce tubes of metal capable of being bent into any required form. The conditions under which it becomes possible to obtain flexibility in tubing are investigated, and it is pointed out that this property depends upon a multiplicity of small segments or moving parts, securely jointed together, provision for movement being made at the joints. In tubes of rigid metal various methods of forming these joints are considered, and it is shown that success can best be obtained in tubes composed of spirally wound strips or fillets of metal, which must be so disposed that the longitudinal joint is not only sound, but is possessed of play or sliding power within certain fixed limits. Owing to the great difficulty experienced in making a good joint of metal against metal, all the earlier attempts to make a flexible joint depended upon the presence of a strip of indiarubber inserted between the coils. In consequence of the liability of indiarubber to deteriorate when employed in this way, it became necessary to devise means to make a tight joint without rubber, and this has now been accomplished. The new flexible metallic tubes are the invention of Mons. E. Levavasseur, and he was led to the discovery by his successful attempts to produce necklaces and bracelets of the well-known snake pattern. In the first instance these ornaments were manufactured by means of spirally wound strips of thin metal of two different sections, so arranged that the joints produced by the lower fillet were covered by a second fillet wound above it, thus, ⌒⌒⌒. At a later date Mons. Levavasseur manufactured similar objects by the use of a single spirally wound fillet in the shape of the letter S, the coils being so disposed that the head of one S was clasped by the tail of the next, and from various modifications in the form of the metal strip many beautiful and flexible chains were thus produced, some of them being subsequently passed beneath a hydraulic press and flattened into an oval section. It will readily be understood that all these tubes were relatively very small in size, and made no pretence of being perfectly tight. About six years ago, however, the inventor, on observing the clumsy contrivances to obtain flexibility in the hose used in Paris for watering the roads, was induced to turn his attention to the fabrication of pipes or tubes of larger dimensions, and this he at first attempted to do by employing the S section already used for jewellery, with the addition of a thin strip of indiarubber inserted along the joint. Some very successful tubes were made in this way, but finding that the rubber was liable to become rapidly worn out, and that in certain cases it soon oxidised or became useless, Mons. Levavasseur determined to prepare a tube in which rubber could be dispensed with. To do this an entirely new section was designed, which may be described as a ⌐⌐ double channel. In coiling this strip the smaller notch fits into the larger one, and room is allowed for a certain amount of play, so that a species of piston joint is obtained, as the small notch works within the larger one in a very similar way to that in which the piston travels in the cylinder. In tubes thus made, it becomes possible to omit the rubber and to obtain a perfectly tight joint between the metal surfaces. The amount of play or flexibility depends to some extent on the size of the pipe, the thickness of the

metal strip employed, and the character of the section. The strips are rolled between a series of molettes, which produce the requisite corrugation, much on the same principle that the larger sections in iron and other metals are rolled in the mill. Recently, by an improvement in the processes of manufacture, it has become possible to produce a flexible pipe in which the coils are soldered together or otherwise united by a tight joint, as the tube is formed, and the flexibility is obtained by the extension and compression of V-shaped folds in the metal. Statistics are given of the strength of various tubes, many of the smaller sections having withstood strains amounting to 2,000 lb. per square inch, and some account follows of the industrial applications of flexible tubing and the numerous purposes in the arts for which this invention may be applicable.

SATURDAY, AUGUST 6.

The Section did not meet.

MONDAY, AUGUST 9.

The following Papers were read:—

1. *Report on Graphic Methods.* *By* Professor H. S. Hele Shaw.[1]
See Reports, p. 373.

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2. *The Destruction of Lightning Protectors by recent Municipal Legislation.* *By* W. H. Preece, *F.R.S.*

The immunity of private houses from being struck by lightning is very marked, and this is considered to be due to the fact that the lead on our roofs and the iron stack-pipes that drain these roofs, connected as they are together, form admirable lightning protectors. Any charge of atmospheric electricity which may fall upon a house so protected is conveyed harmlessly away to the earth. Householders are now required to remove these pipes from direct connection with the drains, and to leave an air space between the end of the pipe and the grating of the drain. The result is that the electric conduction of the pipe is broken, the stack-pipe ceases to be a lightning protector, and houses are left exposed to the dangers of atmospheric electricity.

The remedy is very simple. The pipe need not be entirely cut away; three-fourths of its circular section may be removed for the distance required, and one-fourth may be left to maintain the old electrical connection, or if the separation has been effected, then the stack-pipe should be connected with the drain by a wire or rod so as to restore a path for the charge to the earth.

Householders are also now compelled to put up stack-pipes to ventilate their soil-pipes, erecting above their roofs a metal tube forming a prominent object, exposed to the atmospheric charge, and terminating frequently in an earthenware pipe on the first floor. They are thus liable to be struck by lightning without offering any means of escape. They should be connected electrically with the earth, either directly or indirectly, through the stack-pipes, which would then make them sources of safety rather than of danger.

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[1] Ordered to be printed *in extenso*.

3. *Secondary Batteries in use at the Central Telegraph Office, London, for Telegraphic Purposes.* *By* W. H. Preece, *F.R.S.*

In a paper entitled 'The Use of Secondary Batteries in Telegraphy,' communicated to the British Association at the meeting held at Montreal in 1884, an account of a series of experiments was given which had been carried on during the preceding twelve months to determine the suitability of secondary batteries for telegraphic purposes.

Since that time the use of secondary batteries has been extended, and for the past seven years they have been used to supply current to two large groups of circuits, one group consisting of 110 single needles, and the other of 100 Morse inkers and sounders.

To provide a ready means of replacing the battery in case of failure, the leads from the working and reserve cells, which are placed in the basement, are first led up to the test-board in the instrument room, and there joined to a switch; thence the leads are again led to a test-board in the battery room, where the two groups are split up into sub-groups of ten circuits each. The connections are made in this manner for two reasons: first, for facilitating a change of a faulty battery, and second, to prevent a general stoppage of the whole group in the event of a short circuit at any of the instruments, the resistance of the leads between the instruments and the subdividing connections in the basement being sufficient to prevent more than three ampères being taken from the battery by any one of the instruments, even when a short circuit is on. To prevent any damage to the instruments or risk of fire fuses are placed in the battery leads at each instrument.

The circuits on the groups mentioned are all metropolitan, and are all, approximately, of the same resistance, no equalising resistances being therefore necessary. The current in each circuit ranges between seventeen and twenty milliampères.

The E.M.F. for the single needles is twenty volts, ten cells positive and ten cells negative, with earth in the centre. For Morse working the E.M.F. is eighteen volts.

In addition to these two groups another set of twenty-two cells has been in use since 1889, supplying current for driving the motors of the Delany multiplex distributors. Each of these motors requires a current of about ·12 ampère, and there are ten of them at present driven from this source. Fuses are placed in the leads to each motor. There is no spare set for this work.

A considerable extension of the accumulator system has recently been made, advantage being taken of the transfer of all the Continental service to the General Post Office building in St. Martin's-le-Grand. This transfer was made on October 17, 1891, and since that date the whole of the Continental circuits have been operated by currents from secondary cells.

There are fifty-nine of these Continental circuits, and as they are of various lengths, some requiring repeaters in England, whilst others go direct to the Continent, a somewhat different arrangement has been adopted. In addition to these varying conditions it was found impossible to use the same polarity in all countries, the German, Dutch, and Belgian lines taking positive, and the French negative.

It was also necessary to provide an arrangement which would cause the stoppage of the minimum number of lines should a main fuse be burned or a battery fail.

The fifty-nine lines are divided into four groups; but as the force required for these long lines is 100 volts it is evident that the risks of allowing a dangerously heavy current passing out from the instrument to line, should it make earth near the sending station, are increased. To provide against this, resistances of 100 volts are placed in the battery leads at each instrument, so that it is absolutely impossible that more than one ampère can flow even with earth on the line close up to the instrument. Independent three-ampère fuses are also fitted to each instrument to prevent any damage to lines or instruments should the safety resistance be short-circuited.

As it is sometimes necessary to put repeaters in on the English side of the cable on some lines which nominally work direct to the Continent, the resistance blocks on several of the instruments are wound to 1,000 ohms, and fitted with a switch which enables either 100 ohms or 1,000 ohms to be inserted in the battery circuit, and thus the current is kept constant. In addition to the independent three-ampère fuses main fuses to break at ten ampères are placed on each group of circuits in the accumulator room.

All the coils are kept well charged, and the E.M.F. is not allowed to fall below 1·95 volt per cell. Where spare or reserve sets are provided the charging is carried on at any convenient time, and on those where no spare is in use the charging is done at night, when the minimum disturbance is caused by the slight increase of E.M.F. which is inseparable from simultaneous charging and working.

Accumulators are also used for working the Paris telephone circuits. Their E.M.F. is so constant that they are found to be eminently adapted for the purpose.

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4. *Power Transmission by Alternating Current.* *By* GISBERT KAPP.

Some two years ago the municipal authorities of Cassel, in Germany, determined to become purveyors of electric light, and to place the generating station on the site of the waterworks pumping station, which is situated on the river Fulda, about four miles from the town. The object in choosing this site was partly to bring both undertakings under the same management, and so reduce administrative expenses, but chiefly to utilise an existing turbine plant.

Owing to the great distance between the generating station and the town, it was necessary to work at high pressure and to use some system of transformation in the town, whilst to make the best use possible of the existing power plant it was necessary to combine with the supply some system of storage. This problem was solved in a very successful manner by a German engineer, Herr Oskar von Miller, who had been called in by the municipality to carry out the work. The plan adopted by von Miller was briefly this. He determined to transmit power by single phase alternating current from the generating station to a sub-station or rather to two sub-stations in Cassel, and to use this power for the supply of direct current on the three-wire system. At one of the sub-stations he established a battery which is charged during the hours of light load, and assists the dynamos during the hours of heavy load, so that the maximum power available shall suffice for 3,500-60-C.P. lamps wired.

At the generating station are two 60 K.W. alternators, which can be used singly or in parallel, and the current is transmitted through an underground concentric cable over a distance of about four miles to the sub-stations. The alternators are designed for a terminal pressure of from 2,000 to 2,200 volts, and the loss of pressure in transmission, when both are working full power, is under 10 per cent.

Each sub-station contains an alternating continuous current transformer, consisting of a 60 K.W. alternator, coupled with two continuous current dynamos, one on either side. The latter machines are connected with each other and with the mains in the usual way adopted in three-wire distribution. At one of the sub-stations there is a battery, also arranged on the three-wire system. The mains throughout the district are coupled so that the battery sub-station can supply current to the other sub-station through the town mains. To start any one of the two transformers it is only necessary to switch on the two dynamos which begin to work as motors, and, after observing by a synchroniser that the speed of the alternator has reached the required amount, to close the high pressure alternating current switch, when the alternator works as a motor supplying power to the two dynamos which are directly coupled to it. It will thus be seen that not only are the two alternators at the generating station worked in parallel, but also the two sub-station alternators erected in different parts of the town are worked in parallel. The dynamos are Brown's design and the alternators are my design, both made by the Oerlikon Engineering Works, but I must distinctly state that I can claim no

credit whatever for the Cassel installation; and that the whole credit for this (probably the earliest) example of power transmission by alternating currents is due to von Miller, who, at a time when most electricians were still in doubt as to the possibility of parallel running, boldly laid down a plant, the success of which was not only dependent on parallel running, but also on the economical and safe transmission of power by single phase alternating current, using for this purpose the ordinary type of alternator as made for lighting. The plant was started on May 15 last year, and has been working since then without a hitch.

By the courtesy of Herr von Miller I am able to give the following readings of the working of the battery sub-station taken at my request about a month ago. Although at that time of the year the load is necessarily light the total efficiency of the transformer, even if we neglect the correction due to lag, is satisfactory.

Alternating to Continuous Current Transformer.

Alternating Current Motor				Continuous Current Generators			
				Machine I.		Machine II.	
Speed	Exciting Current	Terminal Volts	Armature Current	Volts	Ampères	Volts	Ampères
500	10	1,820	23	130	120	134	130
460	10	1,800	20	112	120	113	120
475	10	1,840	20	111	125	117	115
475	10	1,800	22	120	128	116	118
470	10	1,800	22	112	127	128	110
465	10	1,820	22	122	115	120	122

5. *A new Electric Locomotive.* *By* E. H. Woods.

The electric locomotive, which is illustrated by the cartoons exhibited, has been designed in the first instance to meet the requirements of heavy traffic on metropolitan railways in substitution of steam.

The only electric railway now working in London (viz., the City and South London) does not seem to fulfil the conditions demanded by the very heavy suburban traffic of the metropolis. It has, however, been in a certain measure successful, as indicating the possibilities of electric traction on railways and the economy to be effected by the use of iron tubular tunnels following the lines of street at a sufficient depth below the surface to avoid sewers and pipes and disturbances to property. The result is that several bills have been promoted during the last session of Parliament for the construction of similar lines in various directions. One of the most important of these is the proposed Great Northern and City Railway, from a point near Finsbury Park station, on the Great Northern Railway, to Finsbury Circus. It differs from the others in that it is intended to run the ordinary passenger trains from the main line of the Great Northern Railway to the heart of the City without change of carriage. To do this it is obvious that electric engines of much greater power are required than those at present in use on the City and South London Railway. It is claimed for this engine that it would fulfil all the conditions which this line demands, whilst, if made on a smaller scale, it would be more economical for working the traffic of the other lines referred to than those at present in use.

It is proposed to work on a central rail similar to that used in the 'Fell' system, and to arrange the electric motors vertically, so that the driving wheels may be horizontal. The necessary adhesion is to be obtained by means of springs, which press the driving wheels against each side of the central rail. One great advantage afforded by this arrangement is that it enables the electric motors to be kept constantly running, even when the engine is stationary, thus avoiding the great loss of power incidental to the starting of the engines now in use. A friction

wheel is interposed between each electric motor and its corresponding driving wheel in such manner that they can all be thrown in and out of gear at the pleasure of the driver.

The electric motors, which are the most delicate part of the machine, are carried on a platform supported by the springs, and consequently are not subject to the shocks caused by inequalities of the road.

Another advantage of this type of engine is that it can be constructed of any reasonable size, and may therefore be far in excess of the power of the largest steam locomotive, which is limited by the size of the boiler. The dead weight also of this engine would be considerably less in proportion to that of the steam locomotive, as the tractive force is obtained by gripping the central rail, and not by gravity. It is especially applicable to lines where the gradients are steep.

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6. *Coin-counting Machine at the Royal Mint.*

By Lieut. W. B. Basset, *R.N.*

It was originally the practice to make up the bronze coinage when ready to be sent out from the Mint into parcels of definite value after they had been 'told up' by the scale in the manner well known to bankers, without actually counting the number. This plan was, however, found to lead to uncertainty, since it requires considerable accuracy to finish coins of exactly equal weight to each other.

Although the average weight of bronze coins is correct it might occur that the aggregate error in a parcel of 1,000 or 1,200 coins would amount to the weight of several pence.

In order to avoid this discrepancy it became necessary to count the bronze coins instead of weighing them, the usual quantity contained in one bag being 5*l.* worth, or 1,200 pence.

The counting has for many years been effected mechanically in two ways. In the first method a man held before him a flat tray, of about 100 square inches area, lined with a brass plate, this plate having in it a number of circular recesses, each capable of receiving and holding a coin. In this tray he placed a quantity of coins, and after shaking them level he threw out the upper layer, leaving a certain number of coins in the recesses of the plate. After filling up any recesses that might be vacant he inverted the tray, allowing the coins, which would be of a known number, to fall out. The operation was then repeated. This method is rather slow and laborious, although very certain, and a step in advance was taken by the construction of a machine having a thin steel plate, rotated by hand, with holes in it disposed in two circles. A tube or hopper is fixed over each circle of holes, with its mouth just clear of the rotating plate, and these tubes are filled up with coins lying flat on each other, thus feeding themselves into the holes in the plate as it revolves, and dropping out before completing a revolution. The machine is stopped by an automatic catch as soon as the plate has revolved a certain number of times. These machines, which were constructed by Messrs. James Watt & Co., of Birmingham, are still in use, and have worked well for a number of years; but a certain amount of trouble and manual labour are required to keep up the supply of coins to the feeding tubes, and the machine which is the subject of this paper has been designed to work with less labour on the part of the attendants than was formerly the case, as well as ensure a greater rapidity.

This machine has now (July 1892) been working at the Royal Mint for six months with satisfactory results. It is capable of counting pence at the rate of fifty per second, or 3,000 per minute, or four bags, each worth 5*l.*, in about one and a half minute, which corresponds to one ton of copper coinage in forty-five minutes.

The machine consists of four separate counters, each of which can be worked independently of the other three. They are placed in pairs, two on the right hand and two on the left, upon a platform or stage, so as to allow head room for an attendant below, thus economising floor space. The coins are brought in a quantity

of a ton at a time upon a trolly, and are contained in bags of half a hundredweight each. Four of these bags are placed upon the cage of a lift, which raises them automatically to such a position that two attendants above can remove them to flat tables, one on each side, upon which they are emptied, and the coins, being spread out, are fed down by hand to a slanting table, where they lie, one coin deep, with their rims touching, a flat superimposed cover preventing the possibility of one coin overlapping another.

From this table they are allowed to move out one at a time, along a groove or channel, the width of one coin, and, being inclined at an angle of 45°, they pass by gravity between the edges of two driving wheels, which are actuated by an electromotor, and which grip the coins as they arrive, forcing them with considerable pressure along the groove. Each coin thus pushes the one in front of it, until they reach a wheel, which is so arranged that its teeth fit into the spaces between the coins, and which is driven round by the coins as they pass it. This is called the counting wheel, since it shows by its revolutions the number of coins that have been delivered. Wheels with teeth of different pitch can be substituted for counting coins of different sizes.

The coins having thus registered themselves fall through a tube into a bag placed at a convenient height from the floor.

The counting wheel, above mentioned, is allowed to revolve until it has delivered a certain number of coins; it is then stopped automatically, and at the same instant the driving wheels, higher up in the groove, are released from acting upon the coins, and cannot again be brought into action until a lever is moved by an attendant. In the meantime the bag containing 1,200 pence, or 5*l.* worth, has been removed, and a fresh bag substituted.

The principal advantage of this method of counting is that an intermittent supply of coins does not affect the accuracy of the count, since if the supply of coins to the driving wheels ceases from any cause the only result is that the wheel stops, and, until a fresh coin starts it, it remains stationary.

The machine at the Mint is capable of counting pence, halfpence, piastres, half-piastres, and Hong Kong cents, and it counts on an average over two million coins per month without error.

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7. *Antifriction Materials for Bearings used without Lubricants.* *By* Killingworth Hedges, *M.Inst.C.E.*

The use of oil as a lubricant in machines is to separate the rubbing parts so as to prevent the interlocking of the metallic particles of the bearings. Heavy lubricants effect this separation better than those of a more limpid kind, but absorb more power.

The actual composition of the metal forming the bearing makes little difference, provided oil in sufficient quantity can be introduced. This is proved by the little wear shown on the cast-iron bearings used for shafting. The use of oil involves loss of power when the pressure per square inch on the bearing is very low, Professor Coleman Sellers considering that even up to 50 lb. on the square inch the viscidity of the unguent acts as a sensible retardant. Dry bearings, or those in which no lubricant is required, although only recently introduced into modern work, were probably the original type of bearings, as they were used in the Roman mill-stones found at Pompeii[1] and up to the present day for all the bearings in the Nubian water-wheels employed for irrigation work in Egypt. In the present time bearings of stone, adamas, and glass have been tried, also a variety of mixtures of plumbago, but none was so successful as the solid form of graphite bearing, which was often employed by millwrights for the footsteps of shafts. A modification has recently been reintroduced into the United States, where the latest form of dry bearing is composed of plumbago mixed with wood fibre and pressed when in a moist condition into suitable moulds. This bearing has been highly praised by the Committee of the Franklin Institute, who state that 'dry

[1] Clarke, *Pompeii*, vol. ii. p. 136.

bearings not only diminish the first cost of construction, but lessen the cost of personal attention, and show a great saving in working cost.'

Many experiments by the author led to the introduction of a material known as carboid, composed of finely powdered carbon mixed with steatite, the mixture having the advantages of plumbago as regards lubricating properties, but showing little signs of wear after tests extending to two years' constant use.

Professor Sellers finds that the coefficient of friction with the dry bearings he experimented on was lower than with metal bearings as usually operated, and points out the advantage they possess of having a constant frictional resistance whether the bearing is run warm or cold, so that the friction can be provided for in the power. Professor Unwin's experiments with carboid show that the co-efficient is independent of the area of contact, and only increases if the temperature becomes excessive, but not with increased pressure, and tends to diminish with increased speed.

General Deductions.—First cost of a dry bearing used for shafting or ordinary machinery is less than with the usual brass or patent metal bearing, and, besides the economy shown by the absence of lubricants, there is saving in the wages required for oiling and cleaning; and in trades where unskilled labour is employed the risk of oiling machinery in motion is entirely obviated; also in mills the drip from oil-cups, besides damaging goods, renders the floors highly inflammable.

Applications of Carboid.—Up to the present time these have been principally for shafting and the bushing of loose pulleys; also for steam-heated rolls such as are used in cloth factories and paper mills. It has been shown experimentally that it can be adapted for use in axle-boxes of tramway cars and for light rolling stock generally, the existing brass being either replaced or a carboid liner cemented in.

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8. *Notes on the Design of Steam Generators especially adapted for High Pressures.*[1] *By* B. H. Thwaite, *C.E., F.C.S., of Liverpool.*

The increasing and laudable desire of engineers to obtain a higher efficiency from their thermo-dynamic motors and steam-generating equipment has directed attention more particularly to the defects and large margin for improvement in the steam generators of the Cornish, Lancashire, and Marine types.

These types the author, in his analysis, unavoidably condemns, and shows that in their design effects of a thermo-chemical and thermo-physical nature, of high importance, are ignored. These effects, he explains, are responsible for the reduction of the strength integrity of the joints, and consequent safety of the steam boiler, and cause structural defects and weakness, requiring constant attention.

The irregular method of heat application in these internal flue-boilers, specified, is criticised, and the result of careful tests in this connection are recorded.

The author formulates a series of axioms that he considers should be respected by the designers of steam-generators, but especially those requiring to withstand very high-working pressures.

The author submits designs of high-pressure safety steam-generators, in which the formulated canons of design of a perfect steam-generator are applied as far as practicable.

The designs submitted are boilers constructed by Messrs. Clark, Chapman & Co., Gateshead, and are of the class known as the tubular type, designed so as to permit the highest pressures to be obtained with safety and with comparatively light metallic proportion of constructional parts.

Smokeless combustion arrangements are described, and methods by which perfect erosive or scale removal circulation is established, and also arrangements by which a certain flexibility of heating surface is obtained, so as to permit of free dilatation or expansion of the transmitting elements of the steam generator.

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[1] The paper is published in *Industries*, vol. i. 1892.

9. *The Strength of Small Chains.*

By Professor H. Hele-Shaw, *M.Inst.C.E.*

The author has frequently found the result of using small chain most unsatisfactory.

In the first place, no small chain which he has been able to procure seemed to give a reasonable amount of strength in proportion to its weight and the tensile strength of the material.

In the second place, no maker will usually give any guarantee of strength below a certain size—generally $\frac{3}{8}$ths of an inch—although in some special cases makers will guarantee the strength as low as $\frac{1}{4}$ inch.

Below $\frac{3}{16}$ths of an inch no strengths are ever quoted in textbooks, engineering pocket-books, or books of engineering reference.

The results are then given of an examination of various well-known books concerning this subject.

From these data, which are not very satisfactory in themselves, it is seen that there are no results for chain of less than $\frac{3}{16}$ inch diameter; whereas enormous quantities of chain under this size are made and sold.

Recently a numerous series of tests on the strength of small chain have been made in the Walker Engineering Laboratory. These tests include all sizes of chain up to $\frac{1}{4}$ inch diameter that could be obtained either in shops or from wholesale makers.

The result of these tests is given in five tables, under the following heads:—

Table I., Single Jack; Table II., Double Jack: Table III., Ordinary Welded; Table IV., Triumph (American); Table V., Miscellaneous (Brazed and Odd-size Welded).

In every size three tests of ultimate strength were made, the results of which, in lbs., have been recorded, the average being given in another column. These tables of results have been plotted in a diagram exhibited, giving the areas in square inches as abscissæ and the strength in lbs. as ordinates. It will be seen that the want of uniformity in results is sufficient to explain why no values for strength are given by the makers, and why the recorded results in books differ so much. Nevertheless there is sufficient agreement to justify the following rules being used to give an approximate idea of strength, though, of course, for working purposes a large factor of safety must be employed:—

Let	P	=	Working strength in lbs.
	A	=	Area in square inches.
	C	=	Constant.
Then	P	=	C A.

The constants are as follows:—

	Kind of Chain	C
(1)	Single Jack	1×10^4
(2)	Double Jack	2×10^4
(3)	Welded	5×10^4
(4)	Triumph	10×10^4

These results are easily remembered, and, as was seen from the lines drawn on the diagram representing the formulæ, give values well below the average strength, and may fairly be taken with the proper factor of safety—say 4—as the working strength of the chain.

The chief effect to be noticed is the extraordinary strength of the new American chain, which, on an average, is twice as strong for every corresponding size as the English Welded Chain; five times as strong as the Double Jack Chain; and nearly eleven times as strong as the Single Jack Chain; and, in most cases, gave way, not as in the case of the Jack Chain and Welded Chain at the joints, but in the material itself.

A further experiment was made of twisting a piece of iron wire into the form of the American link, and then testing the link and afterwards the wire itself,

when it was found that the strength of the link was about $1\frac{3}{4}$ time the strength of a single section of the iron wire from which it was made.

The author understands that this chain is not yet manufactured in this country, but steps are being taken to introduce the machines necessary for the purpose. Specimens of various kinds of chain were exhibited to the Section.

The author acknowledges the assistance of Mr. W. E. Kerslake, Assistant Lecturer in the Walker Engineering Laboratories, in making the tests and preparing the diagrams.

TUESDAY, AUGUST 9.

The following Papers were read :—

1. *Dredgers.* *By* A. Brown.

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2. *Note on Motors used for Fog Signals in the Northern Lighthouse Service.* *By* David A. Stevenson, *B.Sc., F.R.S.E., M.Inst.C.E.*

The paper points out the growing necessity and importance of fog signals on our coast. Details are then given of the duration of fog in this country, the maximum number of hours in Scotland being 395 hours per annum.

The most powerful sound signal in use is stated to have been found by experiment and practice to be the 'Siren,' actuated by compressed air. The various motors are then described; namely, motion of sea by waves and tide, manual labour, clockwork, steam engines, hot-air engines, gas engines, and oil engines. Examples of each are given in detail, and their relative advantages and disadvantages discussed. In conclusion the author states in his view the best motor for fog signal purposes yet tried is undoubtedly the oil engine, and concludes by pointing out how feeble and unreliable at their best are, and must be, fog signals which appeal to the ear, and states that, in his opinion, the solution of the matter will probably be found in the adoption of some such method as that recently proposed by Mr. Charles A. Stevenson, namely, an electric cable or conductor laid down off a coast or danger, so as to act on an instrument attached to each vessel, and so warn the sailor of his proximity to it, and therefore to the coast or danger.

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3. *On the Progress of the Dioptric Lens as used in Lighthouse Illumination.* *By* Charles A. Stevenson, *B.Sc., F.R.S.E., M.Inst.C.E.*

Fresnel, in 1820, devised and constructed a lens for first-order lights of 920 mm. focal distance. It was composed of a central lens, with refracting prisms concentric with it, which gradually decreased in breadth as they receded from the centre. The separate pieces of which these lenses were made up were cemented together and mounted in metallic frames 30 inches square.

In 1835 the late Mr. Alan Stevenson introduced the Fresnel apparatus into Great Britain. In doing so he made several improvements, one of which was that he increased the height of the lens from 30 to 39 inches. This refractor had eight prisms above and eight prisms below the central lens. Since that time Alan Stevenson's lens was almost universally used until a comparatively recent date, when a revolution in the size of lenses took place. A few years ago inventors were trying to obtain greater power by increasing the diameter and volume of the flames; but Messrs. Stevenson pointed out, in 1869, that after a certain point an increase of diameter of the luminary not accompanied by a corresponding increase of the radius of the apparatus was a mistake, as the light became exfocal and hence divergent, and that the proper way to secure greater power was to enlarge the *diameter* of the apparatus. In 1885 they had a lens made to their design of

1,330 mm. focal distance, and a height of 5 feet. This lens, which was named 'hyper-radiant,' was tried at the South Foreland against other lenses, and with a large ten-ring gas burner it was found to give a light from one and a half to twice as intense as the ordinary lenses which were pitted against it with the same large burners in their foci, thus proving conclusively that to get the power out of large burners it was imperatively necessary to increase the diameter of the apparatus. In 1883 Messrs. Stevenson got an offer from Messrs. Barbier for a lens of 1,840 mm. focal distance.

All refracting lenses from the day of Alan Stevenson were cylindrical for fixed lights, and plano-convex for revolving lights, and no alteration of any moment has been made in the mode of their construction until 1886, when, instead of making the lenses cylindrical or plano-convex, I proposed to give them a spherical form—that is to say, circular not only in the horizontal but also in the vertical section. This design was carried into practice in the apparatus for one of the Fair Isle lighthouses. The introduction of the spherical refractor has made practicable the construction of very much larger and, consequently, more powerful apparatus, and occupying much less space both in the daylight size and diameter of lantern. It has rendered practicable the quadrilateral arrangement with hyper-radiant lenses which have already been erected at Fair Isle, the lenses being cut so as to give two flashes from each side of the quadrilateral. An experimental one, made for Mr. Wigham, is to be tried in Ireland. It is 2 m. focal distance, and the spherical refractor is 7 ft. 6 in. in diameter, and will give one flash from each side of the quadrilateral. The spherical refractor should not be carried too far above the focal plane, and equiangular prisms should then be employed.

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4. *Smoke-consuming Apparatus.* *By* A. R. Sennett.

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5. *A System of Purifying the Smoke from Domestic and other Fires.* *By* Colonel E. Dulier.

This process consists in mixing the smoke as it leaves the flue with a small quantity of steam, generated in a boiler forming part of the kitchen range.

The mixed steam and smoke pass into an open chamber, the top part of which is provided with a number of pipes, placed in the direction of the prevailing wind, through which the air passes and helps to cool the gases. At the extreme top of this chamber, just before passing into the atmosphere, the gases are met by a very fine shower of water issuing from minute holes in a pipe.

The result of this treatment is a very thorough washing of the smoke, and the almost complete removal of all solid matters (soot and dust) and a large proportion of the sulphurous acid always present in coal smoke. The removal of the soot and dust is so perfect that a piece of wet cotton held in the issuing gases remains perfectly white even after a lengthened exposure.

The amount of steam required is small, and may be neglected in an estimate of the cost of working the process, as it is generated by means of heat which would not otherwise be available for any useful purpose. The only item of cost to consider is that of water. The amount used in the apparatus at Sloane Gardens is found to be about ten gallons per hour; this includes the condensed water from the steam.

This apparatus treats the smoke from a large kitchen range burning about 20 lb. of coal per hour, but it is capable of treating the smoke from several such fires. It is important to notice that the draught is not sensibly impaired by the apparatus, any slight retarding of the flow of the gases being more than compensated by the action of the jet of steam.

The results of a number of experiments with the apparatus at atmospheric temperatures varying from 92° Fahr. (33°·3 C.) in the shade (part of the time the apparatus was exposed to direct sunshine) to 50° Fahr. (10° C.) showed that

almost the whole of the soot was removed and a considerable proportion of the sulphurous acid.

It may be mentioned that the apparatus is exceedingly simple to work, being in fact almost automatic.

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6. *The London Sewage Question.* *By* CRAWFORD BARLOW, *B.A., M.I.C.E.*

The following observations and suggestions are made on the assumption that the recommendations of the joint report of Sir B. Baker and Mr. Binnie are carried out. This report advises that two new intercepting sewers shall be constructed, one north and the other south of the Thames, which are to discharge at the present outfalls; and it suggests that a decision in respect to the question of disposal shall be postponed until the present arrangements have been tested.

A considerable reduction of the difficulties will be effected if the volume of the liquid to be dealt with is reduced, say, by conveying some of the rain direct to the river. Suggestions of somewhat similar character have been already considered and condemned on account of the great cost and interference with private property, but an arrangement whereby a partial separation of rain from sewage (to be accomplished by conducting the rain off roads, open spaces, squares, parks, public buildings, &c., direct to the river) would, while being effective, avoid these objections.

There are certain old sewers which were constructed in times past in the valleys and hollows, and were made of large dimensions, so as to be able to convey the flood waters to the river before the main drainage system was designed.

Five of these—the Ranelagh, the King's Scholars Pond, and the Fleet on the north side of the Thames, the Falcon and the Effra on the south—are capable of discharging large volumes of liquid, and, in fact, are the ones which now chiefly relieve the main drains in times of heavy rains.

To utilise these for carrying off rain water only, intercepting sewers could be constructed on each side of them, to be connected with the nearest main drainage sewers, and the rainfall from all the neighbouring streets could be conveyed by small conduits into these great carriers, and so direct to the river. Also new conduits could be constructed for taking off rain water only to the river.

The great advantage of such an arrangement is, that the liquid so conveyed would involve no further expense, whereas if the same liquid were conveyed by intercepting sewers to the outfalls it would, in consequence of its mixture with sewage, have to be chemically treated, and the resulting sludge removed.

The main objection to the present system is the discharge of sewage into the river—either by storm overflows or in the form of effluent or sludge.

The dry weather quantity of sewage is given at the present time as 180,000,000 gallons per diem, but when the proposed new intercepting drains are completed the total amount of sewage discharge at Barking and Crossness will be close upon 300,000,000 gallons per diem, and the resulting effluent must produce most disastrous results to the river for miles on each side of the outfalls.

The amount of sludge is at the present time 40,000 tons per week, but when these new arrangements come into operation it will be increased to 70,000 tons (of which 7,000 tons is absolutely solid matter), and the deposition of this amidst the sandbanks at the mouth of the Thames will most assuredly affect the width, depth, and position of the navigable channels there, and thereby cause obstruction to the navigation, with the great probability of deposits of sewage mud being formed on all the shoals and shores in the neighbourhood.

In dealing with this question neither Londoners nor the many other persons who are interested in the sanitary condition of the river should permit the London County Council to depart in any way from the recommendations of the Royal Commission of 1884, that is to say, that they shall not allow them to discharge any effluent into the river nearer London than Hole Haven, or to deposit sludge anywhere except in the open sea; and as these conditions will involve an enormous expense fresh considerations should be given to a *land treatment*, especially as Berlin,

Paris, and many other cities have adopted this method (and according to the latest accounts) with great success.

Land treatment would be best effected by pumping up the sewage from the north side at Abbey Mills to an elevation of about 50 or 60 feet above ordnance datum, and conveying it by a conduit passing along the contour; an area of land of over 50,000 acres would be thus available for the selection of farms. The termination of this conduit might be made either at Hole Haven or at some convenient place on the river Crouch, and there such liquid as was not used on the land could be disposed of either chemically or in any other manner thought advisable.

It is to be borne in mind that if a portion of the rain is carried direct to the river, as has been suggested, the liquid in the sewers will be less in quantity and not so variable, whilst it will be more concentrated, and hence better suited for placing on land.

In Sir B. Baker's and Mr. Binnie's report one of the suggestions for the future alleviation of the discharge of sewage into the Thames at the present outfalls is the construction of a new outfall sewer from Barking to Shell Haven.

If some modification were made in the laying out of this, it could be arranged for a commencement of a land treatment.

The London ratepayers are not so much affected by the unsanitary condition of the river as other persons and interests outside the boundary of the London County Council's jurisdiction: consequently it would seem that the London sewage system should be controlled by a trust or corporation which should include representatives of all the different and various interests which are affected by the disposal of the London sewage; such as the ratepayers of London (represented by the London County Council), the traders, dockowners, shipowners, manufacturers (represented by the London Chamber of Commerce), and residents along the shores of the river, and all who are affected by the sewage.

With regard to the important question of ways and means, in addition to the amount which the London County Council can procure from the ratepayers, a further revenue might be obtained by taxing all persons, manufacturers, dock and ship owners who foul the river in any way. Such arrangement would doubly assist to purify the Thames.

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7. *City Sanitation as practically conducted in Edinburgh.* By John Cooper, *Assoc.M.Inst.C.E.*

The intention of the author in submitting this paper is to give a short review, chiefly from an engineering standpoint, of the sanitary equipment of the city of Edinburgh, and the methods which have been and are being pursued by the civic authorities for the health, comfort, and convenience of the community.

I. Edinburgh: its population; area; public parks: density of population; death-rate: administrative and executive machinery; rateable value; taxes.

II. Edinburgh and district water supply; composition of Board of Water Trust; short account of successive schemes of supply; sources, area, and amount of supply; quality of water; extent to which water is used for sanitary purposes; description of additional supply proposed. (Illustrated with maps.)

III. The sewage systems of Edinburgh; the physical advantages of Edinburgh for efficient drainage and sewage disposal; natural divisions and outlets; kind of sewers; gradients; amount of sewage discharged daily; points of discharge; sewage as applied to land by surface irrigation; Craigentinny meadows; short account of same; methods of application of sewage; crops; profits; costs of attendance; amount of outlay during the last ten years in forming large sewers and sewage outfalls, &c. (Illustrated with maps.)

IV. Water of Leith purification and sewerage scheme; the insanitary condition of this river owing to pollution landward and urban, and its effect upon Edinburgh and Leith; the principles of the purification scheme presently being carried out; composition of the Board of Commissioners charged with the carrying out of the scheme; the extent and nature of the works; cost of same; how levied;

beneficial results from a sanitary point of view; and to the amenity of the districts through which the river flows. (Illustrated with maps.)

V. Drainage and sanitary appliances of dwelling-houses; advantages derived in having advanced sanitarians in Town Council; measures adopted for securing freedom from risks of faulty drainage or defective sanitary appliances; methods of inspection; sources of complaints; evidence of appreciation on the part of the citizens of the services of Sanitary Department; extent to which this inspection carried out during the last ten years; cost of same; further statutory powers acquired in 1891; extent of increase of new houses during the last five years; inspection and certification of said new houses.

VI. Edinburgh slums; characteristics; past schemes of city improvements; necessity for Dr. Chambers's scheme, 1867; cost and beneficial results; methods adopted by Town Council in following up Dr. Chambers's scheme; work of voluntary societies in aid of work of Town Council; results; necessity for further improvement; proposals for new city improvement schemes; account of various schemes for providing houses for working classes.

VII. Methods of collection; removal and disposal of city refuse; staff; present means of disposal; new method by cremation in course of preparation. (Illustrated with map and plans.)

VIII. General remarks on the growing requirements of city life.

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8. *On the Extinction of Fires in Ships' Holds.* *By* H. C. Carver.

It is pointed out in the paper that the conditions peculiar to fires in ships' holds and on land respectively differ widely, and that methods of extinction valuable in the one case are comparatively useless in the other. Examples of this are cited.

It is practicable to establish throughout a ship's hold a plenum of an artificial atmosphere deadly to fire; and if such a plenum be maintained long enough to allow the heated materials of a fire to cool down to below their temperature of ignition, the fire peril will be subdued with certainty. Unless, however, a plenum of the artificial atmosphere be maintained, there is danger of fresh air leaking into the hold, and keeping the fire alive.

Numerous plans have been devised for putting into ships' holds fire-annihilating gases, produced by chemical reaction, in quantities altogether insufficient for establishing a plenum. It appears to the author that such plans are unsatisfactory, not only owing to the failure to produce a plenum in the holds, but also because shipowners would be unwilling to have their vessels constantly burdened with a supply of special reagents large enough to yield a continuous production of gas for days together.

Owing to these objections, the author thinks that the efficient protection of vessels against hold fires by the injection of an artificial atmosphere would be, commercially speaking, impracticable, were there no means, other than the employment of special chemical reagents, available for the purpose.

Fortunately, in steamers at least, there are other means, always ready to hand, which meet the requirements quite satisfactorily. For the boiler furnace fumes are a fire-annihilating medium; and the volume of these, flowing to waste from a steamer at sea, is largely in excess of what is required for maintaining a plenum in a hold.

An apparatus applicable to steamers is described, for abstracting a sufficient quantity of furnace fumes from their ordinary passages to the air, for cooling the fumes by water to a temperature of 80° to 90° Fahr., and for forcing them into the holds through pipes. The apparatus has no moving parts, and is set in action by merely turning on three valves.

The character of the apparatus, the unfailingness of the fumes supply, and the efficacy of the fumes against fire combine to render the system a thoroughly dependable one.

The apparatus is so arranged that it can also be used for rapidly ventilating a hold in an emergency.

Tugs and salvage steamers can be fitted with the apparatus to protect other vessels in port.

Sailing vessels not having donkey boilers require a modified type of the apparatus, embracing a furnace in which to burn coal for the production of fumes.

Examples are cited of the employment of furnace fumes in extinguishing fires.

Allusion is made to the frequent practice of using steam against fires in steamers' holds, and the author states his views regarding the capabilities of this system, arguing that, though it is of great value in many cases, it cannot be relied on with certainty.

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9. *On a new Form of Steam Brake for Locomotives.* By William Cross, *C.E.*

It is not known who was the originator of the plan of fitting a small steam cylinder to relieve and assist the fireman in the hard manual labour of 'setting the brakes,' but so obvious a device was scarcely likely to have escaped attention even in the early days of locomotive engineering. Though the arrangement was exceedingly simple and powerful it was soon found to possess many grave disadvantages, the chief of these being the difficulty of properly graduating the action so as to pull up the train steadily without jerk, and the impossibility of keeping an even pressure in the cylinder for any length of time as required when descending long grades. Various forms of reducing valves have been tried from time to time, but to the best of the writer's knowledge none of these has proved very satisfactory or reliable in practice. For these reasons it was found the fireman always preferred to use the hand brake, on the action of which he could rely, only using the steam brake in cases of emergency, with the then great probability of either being too late to be of any service, or of its not working properly on account of disuse.

It seemed to the writer that the only way to make a steam brake of real value would be to fit it in such a way that the men were compelled to use it every time they applied the hand brake, and to make its action coincide with that of the latter in such manner that the further the handle was pulled round, the harder the steam brake would go on, and *vice versâ*.

The practical way in which this idea is carried out consists in arranging a floating lever or hunting screw between the usual vertical rod of the hand brake and the valve controlling the steam supply of the steam brake cylinder in such a way that, as the man commences to turn the handle to put on the hand-brake, he admits steam to the brake cylinder; but the piston of the latter, so soon as it commences to move, cuts off its own supply through the agency of the floating lever. If, therefore, he continues to turn the handle, the piston moves in exact accordance with it until the maximum available steam pressure is reached; if he now still continues to turn, the hand brake comes into action in the ordinary manner, and this latter also takes place if the steam were altogether shut off from the brake cylinder at the boiler.

The action thus nearly resembles that used in steam steering gear, gun training gear, steam reversing gear, &c., and has been aptly described as 'making a thing move two ways at the same time.'

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10. *On a new Form of Gas Engine.* By Joseph Day, *A.M.Inst.C.E.*

For practical purposes it may be assumed that all gas engines are worked on one of two systems or cycles, viz., that of Beau de Rochas, involving an impulse every *other* revolution, and that under which an impulse is obtained at *every* revolution. The former has been made so world-renowned by the Messrs. Crossley that no long explanation is needed. Suffice it to say that in an engine constructed upon this cycle the piston acts *alternately* as a pump and as a motor. The only objection that can be urged against this system is that as only every other stroke of the engine is available for *useful* work, the proportions and magnitude of the engine, as compared with an engine doing work at each stroke, must be as 2 : 1.

Further, there is the necessity for equalising the power thus intermittently given off by means of a heavy fly-wheel.

Several attempts have been made to obtain a satisfactory engine upon the other cycle, viz., that under which impulse is obtained at every revolution. This result was accomplished by the old type of Stockport engine, by Mr. D. Clerk's engine, and others; but in all these engines a second cylinder was provided in which a supplementary piston did the work alternately done by the working piston in the cycle first referred to.

This led to complication and loss of efficiency, and the principle has, speaking generally, been abandoned.

With the object of combining the advantages of both systems the writer developed and completed the engine now known as the 'Day' gas engine.

In this engine simplicity has been the principal object sought, and it is difficult to see how a gas engine could be made to work with simpler or fewer parts.

The construction of the engine is as follows:—

The piston is of the trunk form, and through a connecting rod works on to the crank pin. The crank works in an inclosed chamber, the crank shaft projecting through a boss bearing, terminating in a gland.

On the upward stroke of the engine it is obvious that a partial vacuum is produced by the retreat of the piston, and this vacuum is taken advantage of to induce a flow of gas and air, in controlled proportions, into the crank chamber through an automatic reflex action valve. It is equally clear that on the downward movement of the piston the mixture thus introduced is compressed—in practice, it is compressed to about 2 lb. to the inch—and by this means is possessed of sufficient motive power to charge the working end of the cylinder. This is accomplished by the following device:—Communicating from the crank chamber to the lower part of the working end of the cylinder is a port or passage, and this is closed by the piston until the latter, at the end of its stroke, uncovers it. Immediately the gas mixture, being compressed as explained, flies up through the passage and charges the cylinder; the piston returns, closes the port, compresses the mixture in the usual way against an ignition tube, and an explosion results, causing the descent of the piston. The exhaust of the waste products is accomplished by the opening of a somewhat similar port communicating to the atmosphere *opposite* the inlet port above described, which is opened by the piston slightly in advance of the opening of the inlet port. Thus, when the incoming charge is admitted, the explosion in the cylinder has been reduced to atmospheric pressure. The incoming charge is made to assist in the clearance of the waste products by its being diverted upwards by a fin on the top of the piston, and thus setting up an eddying action, tending to drive out the contents of the cylinder through the open exhaust port. Thus it will be seen that with one piston and one cylinder an impulse is obtained at every revolution of the engine. It will also be apparent that the engine will run with equal facility and efficiency in either direction.

The speed obtainable is very great, there being no tappets, cams, or levers, and in a small engine as much as 1,100 revolutions per minute have been obtained. At this speed firing was irregular, but at 500 revolutions the explosions were absolutely regular.

For the same reason the engine runs extremely quietly.

The writer claims to have produced an engine—

(1) With fewer working parts than any other.
(2) That occupies less space.
(3) That without any alteration will run in either direction.
(4) That, owing to the absence of friction, possesses a high degree of mechanical efficiency.
(5) That runs more silently than any other gas engine.

Section H.—ANTHROPOLOGY.

President of the Section—Alexander Macalister, M.D., F.R.S., Professor of Anatomy in the University of Cambridge.

THURSDAY, AUGUST 4.

The President delivered the following Address:—

On an irregular and unfenced patch of waste land, situated on the outskirts of a small town in which I spent part of my boyhood, there stood a notice-board bearing the inscription 'A Free Coup,' which, when translated into the language of the Southron, conveyed the intimation, 'rubbish may be shot here.' This place, with its ragged mounds of unconsidered trifles, the refuse of the surrounding households, was the favourite playground of the children of the neighbourhood, who found a treasury of toys in the broken tiles and oyster-shells, the crockery and cabbage-stalks, which were liberally scattered around. Many a make-believe house and road, and even village, was constructed by these mimic builders out of this varied material, which their busy little feet had trodden down until its undulated surface assumed a fairly coherent consistence.

Passing by this place ten years later I found that its aspect had changed; terraces of small houses had sprung up, mushroom-like, on the unsavoury foundation of heterogeneous refuse. Still more recently I notice that these in their turn have been swept away, and now a large factory, wherein some of the most ingenious productions of human skill are constructed, occupies the site of the original waste.

This commonplace history is, in a sense, a parable in which is set forth the past, present, and possible future of that accumulation of lore in reference to humanity to which is given the name Anthropology, and for the study of which this Section of our Association is set apart. At first nothing better than a heap of heterogeneous facts and fancies, the leavings of the historian, of the adventurer, of the missionary, it has been for long, and, alas! is still, the favourite playground of *dilettanti* of various degrees of seriousness. But upon this foundation there is rapidly rising a more comely superstructure, fairer to see than the original chaos, but still bearing marks of transitoriness and imperfection, and I dare hazard the prediction that this is destined in the course of time to give place to the more solid fabric of a real science of anthropology.

We cannot yet claim that our subject is a real science in the sense in which that name is applied to those branches of knowledge, founded upon ascertained laws, which form the subjects of most of our sister Sections; but we can justify our separate existence, in that we are honestly endeavouring to lay a definite and stable foundation upon which in time to come a scientific anthropology may be based.

The materials with which we have to do are fully as varied as were those in my illustration, for we as anthropologists take for our motto the sentiment of Chremes, so often quoted in this Section, *humani nihil a nobis alienum putamus*, and they are too often fully as fragmentary. The bones, weapons, and pottery

which form our only sources of knowledge concerning prehistoric races of men, generally come to us as much altered from their original forms as are the rusty polyhedra which once were the receptacles for biscuits or sardines. The traditions, customs, and scraps of folk-lore which are treasures to the constructive anthropologist are usually discovered as empty shells, in form as much altered from their original conditions as are those smooth fragments of hollow white cylinders which once held the delicate products of the factory of Keiller or Cairns.

I have said that anthropology has not yet made good its title to be ranked as an independent science. This is indicated by the difficulty of framing a definition at the same time comprehensive and distinctive. Mr. Galton characterises it as the study of what men are in body and mind, how they came to be what they are, and whither the race is tending; General Pitt-Rivers, as the science which ascertains the true causes for all the phenomena of human life. I shall not try to improve upon these definitions, although they both are manifestly defective. On the one side our subject is a branch of biology, but we are more than biologists compiling a monograph on the natural history of our species, as M. de Quatrefages would have it. Many of the problems with which we deal are common to us and to psychologists; others are common to us and to students of history, of sociology, of philology, and of religion; and, in addition, we have to treat of a large number of other matters æsthetic, artistic, and technical, which it is difficult to range under any subordinate category.

In view of the encyclopædic range of knowledge necessary for the equipment of an accomplished anthropologist, it is little wonder that we should be, as we indeed are, little better than smatterers. Its many-sided affinities, its want of definite limitation, and the recent date of its admission to the position of an independent branch of knowledge have hitherto caused anthropology to fare badly in our universities. In this respect, however, we are improving, and now in the two great English universities there are departments for the study of the natural history of man and of his works.

Out of the great assemblage of topics which come within our sphere I can only select a few which seem at present to demand special consideration. The annual growth of our knowledge is chiefly in matters of detail which are dull to chronicle, and the past year has not been fertile in discoveries bearing on those great questions which are of popular interest.

On the subject of the antiquity of man there are no fresh discoveries of serious importance to record. My esteemed predecessor at the Leeds meeting two years ago, after reviewing the evidence as to the earliest traces of humanity, concluded his survey with the judgment, 'On the whole, therefore, it appears to me that the present verdict as to Tertiary man must be in the form of "Not Proven."' Subsequent research has not contributed any new facts which lead us to modify that finding. The most remarkable of the recent discoveries under this head is that of the rude implements of the Kentish chalk-plateau described by Professor Prestwich; but while these are evidently of archaic types, it must be admitted that there is even yet room for difference of opinion as to their exact geological age.

Neither has the past year's record shed new light on the darkness which enshrouds the origin of man. What the future may have in store for us in the way of discovery we cannot forecast; at present we have nothing but hypothesis, and we must still wait for further knowledge with the calmness of philosophic expectancy.

I may, however, in this connection refer to the singularly interesting observations of Dr. Louis Robinson on the prehensile power of the hands of children at birth, and to the graphic pictures with which he has illustrated his paper. Dr. Robinson has drawn, from the study of the one end of life, the same conclusion which Mr. Robert Louis Stevenson deduced from the study of his grandfather, that there still survive in the human structure and habit traces of our probably arboreal ancestry.

Turning from these unsolved riddles of the past to the survey of mankind as it appears to us in the present, we are confronted in that wide range of outlook with many problems well-nigh as difficult and obscure.

Mankind, whenever and however it may have originated, appears to us at present as an assemblage of tribes, each not necessarily homogeneous, as their component elements may be derived from diverse genealogical lines of descent. It is much to be regretted that there is not in our literature a more definite nomenclature for these divisions of mankind, and that such words as *race*, *people*, *nationality*, *tribe*, and *type* are often used indiscriminately as though they were synonyms.

In the great mass of knowledge with which we deal there are several collateral series of facts, the terminologies of which should be discriminated. In the first place there are those ethnic conditions existing now, or at any other point in time, whereby the individuals of mankind are grouped into categories of different comprehension, as *clans* or families, as *tribes* or groups of allied clans, and as *nations*, the inhabitants of restricted areas under one political organisation. This side of our subject constitutes ethnology.

In the second place, the individuals of mankind may be regarded as the descendants of a limited number of original parents, and consequently each person has his place on the genealogical tree of humanity. As the successive branches became in their dispersion subjected to the influences of diverse environments, they have eventually differentiated in characteristics. To each of these subdivisions of the phylum thus differentiated the name *race* may appropriately be restricted, and the sum of the peculiarities of each race may be termed *race-characters*. This is the phylogenetic side of anthropology, and its nomenclature should be kept clearly separate from that of the ethnological side. The great and growing literature of anthropology consists largely of the records of attempts to discover and formulate these distinctive race-characters. *Race* and *tribe* may be terms of equal extension, but the standpoint from which these categories are viewed is essentially different in the two cases.

There is yet a third series of names in common use in descriptive anthropology. The languages in use among men are unfortunately numerous, and as the component individuals in each community usually speak a common language, the mistake is often made of confounding the tribal name with that of the tribal language. Sometimes these categories are co-extensive; but it is not always so, for it is a matter of history that communities have been led to adopt new languages from considerations quite independent of phylogenetic or ethnic conditions. These linguistic terms should not be confounded with the names in either of the other series, for, as my learned predecessor once said in a presidential address, it is as absurd to speak of an Aryan skull as it would be to say that a family spoke a brachycephalic language.

In the one clan there may be, by intermarriage, the representatives of different races; in the one nation there may be dissimilar tribes, each derived by composite lines of ancestry from divergent phyla, yet all speaking the same language.

We have an excellent illustration of the confusion resulting from this disregard of precision in the case of the word *Celtic*, a term which has sometimes been employed as an ethnic, sometimes as a phylogenetic, and sometimes as a linguistic species. In the last-named sense, that to which I believe the use of the name should be restricted, it is the appropriate designation of a group of cognate languages spoken by peoples whose physical characters show that they are not the descendants of one common phylum in the near past. There are fair-haired, long-headed families in Scotland and Ireland: fair, broad-headed Bretons; dark-haired, round-headed Welshmen; and dark-haired, long-headed people in the outer Hebrides, McLeans, 'Sancho Panza type'—men obviously of different races, who differ not only in colour, stature, and skull-form, but whose traditions also point to a composite descent, and yet all originally speaking a Celtic tongue. The use of the word *Celtic* as if it were the name of a phylogenetic species has naturally led to hopeless confusion in the attempts to formulate race-characters for the Celtic skull—confusions of a kind which tend to bring physical anthropology into discredit. Thus Retzius characterises the Celtic crania as being dolichocephalic, and compares them with those of the modern Scandinavians. Sir Daniel Wilson considers the true Celtic type of skull as intermediate between the dolichocephali

and the brachycephali; and Topinard figures as the typical Celtic skull that of an Auvergnat, extremely brachycephalic, with an index of 85!

Our traditional history tells that we, the Celtic-speaking races of Britain, are not of one common ancestry, but are the descendants of two distinct series of immigrants, a British and a Gaelic. Whatever may have been the origin of the former, we know that the latter are not homogeneous, but are the mixed descendants of the several Fomorian, Nemedian, Firbolg, Tuatha de Danaan, and Milesian immigrations, with which has been combined in later times a strong admixture of Scandinavian blood. It is now scarcely possible to ascertain to which of these component strains in our ancestry we owe the Celtic tongue which overmastered and supplanted the languages of the other tribes, but it is strictly in accordance with what we know of the history of mankind that this change should have taken place. We have instances in modern times of the adoption by conquered tribes of the language of a dominant invading people. For example, Mr. Hale has lately told us that the speech of the Hûpas has superseded the languages of those Californian Indians whom they have subdued. In like manner, nearer home, the English language is slowly but surely supplanting the Celtic tongues themselves.

We may here parenthetically note that what has been observed in the case of language has also taken place in reference to ritual and custom. Observances which have a history and a meaning for one race have, in not a few instances, been adopted by or imposed upon other races to whom they have no such significance, and who in incorporating them give to them a new local colour. These pseudomorphs of the earlier cultures are among the most perplexing of the problems which the student of comparative religion or folk-lore has to resolve.

But we want more than a perfect nomenclature to bring anthropology into range with the true sciences. We need a broader basis of ascertained fact for inductive reasoning in almost all parts of our subject; we want men trained in exact method who will work patiently at the accumulation, verification, and sorting of facts, and who will not prematurely rush into theory. We have had enough of the untrained writer of papers, the jerry-builder of unfounded hypotheses whose ruins cumber our field of work.

The present position of our subject is critical and peculiar; while on the one hand the facilities for anthropological research are daily growing greater, yet in some directions the material is diminishing in quantity and accessibility. We are accumulating in our museums treasures both of the structure and the works of man, classified according to his distribution in time and space; but at the same time some of the most interesting tribes have vanished, and others are rapidly disappearing or becoming fused with their neighbours. As these pass out of existence we, with them, have lost their thoughts, their tongues, and their traditions; for even when they survive, blended with other races, that which was a religion has become a fragmentary superstition, then a nursery tale or a child's game, and is destined finally to be buried in oblivion. The unifying influences of commerce, aided by steam and electricity, are effectually effacing the landmarks between people and people, so that if we are to preserve in a form fit for future use the shreds which remain of the myths, folk-lore, and linguistic usages of many of the tribes of humanity, we must be up and doing without delay. It is on this account that systematic research such as that which Mr. Risley has advocated with regard to the different races of India is of such pressing and urgent importance. It is for this reason likewise that we hail with pleasure the gathering of folk-lore while yet it survives, and welcome such societies for the purpose as the Folk-lore Congress recently inaugurated.

I have said that in the department of physical anthropology our facilities for research are increasing. The newly founded anthropometric laboratories are beginning to bring forth results in the form of carefully compiled statistical tables, embodying the fruits of accurate observations, which are useful as far as they go. Were these extended in their scope the same machinery might easily gather particulars as to the physical characters of the inhabitants of different districts, which would enable the anthropologist to complete in a systematic manner the work

which Dr. Beddoe has so well begun. I would commend this work to the consideration of the provincial university colleges, especially those in outlying districts.

Of all the parts of the human frame, the skull is that upon which anthropologists have in the past expended the most of their time and thought. We have now, in Great Britain alone, at least four collections of skulls, each of which includes more than a thousand specimens, and in the other great national and university museums of Europe there are large collections available for study and comparison.

Despite all the labour that has been bestowed on the subject, craniometric literature is at present as unsatisfactory as it is dull. Hitherto observations have been concentrated on cranial measurements as methods for the discrimination of the skulls of different races. Scores of lines, arcs, chords, and indexes have been devised for this purpose, and the diagnosis of skulls has been attempted by a process as mechanical as that whereby we identify certain issues of postage-stamps by counting the nicks in the margin. But there is underlying all these no unifying hypothesis, so that when we, in our sesquipedalian jargon, describe an Australian skull as microcephalic, phænozygous, tapeino-dolichocephalic, prognathic, platyrhine, hypselopalatine, leptostaphyline, dolichuranic, chamæprosopic, and microseme, we are no nearer to the formulation of any philosophic concept of the general principles which have led to the assumption of these characters by the cranium in question, and we are forced to echo the apostrophe of Von Török, 'Vanity, thy name is Craniology.'

It was perhaps needful in the early days of the subject that it should pass through the merely descriptive stage; but the time has come when we should seek for something better, when we should regard the skull not as a whole complete in itself, nor as a crystalline geometrical solid, nor as an invariable structure, but as a marvellously plastic part of the human frame, whose form depends on the co-operation of influences, the respective shares of which in moulding the head are capable of qualitative if not of quantitative analysis. Could measurements be devised which would indicate the nature and amounts of these several influences, then, indeed, would craniometry pass from its present empirical condition and become a genuine scientific method. We are yet far from the prospect of such an ideal system, and all practical men will realise the immense, but not insuperable, difficulties in the way of its formulation.

In illustration of the profound complexity of the problem which the craniologist has to face, I would ask your indulgence while I set out a few details to show the several factors whose influence should be numerically indicated by such a mode of measurement.

The parts composing the skull may be resolved into four sets: there is, first, the brain-case; secondly, the parts which subserve mastication and the preparation of the food for digestion; thirdly, the cavities containing the organs of the senses of hearing, sight, and smell; and, fourthly, those connected with the production of articulate speech. If our measurements are to mean anything, they should give us a series of definite numbers indicating the forms, modifications, and relative size of these parts, and their settings with regard to each other and to the rest of the body.

To take the last point first, it needs but a small consideration to show that the parts of the skull are arranged above and below a certain horizontal plane, which is definite (although not easily ascertained) in every skull, human or animal. This is the plane of vision. The familiar lines of Ovid—

> Pronaque cum spectent animalia cetera terram,
> Os homini sublime dedit; cœlumque tueri
> Jussit, et erectos ad sidera tollere vultus—

are anatomically untrue, for the normal quadruped and man alike, in their most natural position, have their axes of vision directed to the horizon. Systems of measurement based upon any plane other than this are essentially artificial. There are at the outset difficulties in marking the plane accurately on the skull, and it is to be deplored that the anthropologists of different nations should

have allowed themselves to be affected by extraneous influences, which have hindered their unanimous agreement upon some one definite horizontal plane in craniometry.

The Frankfort plane drawn through the upper margins of the auditory foramina and the lowest points of the orbital borders has the advantage of being easily traced, and differs so little from the plane of vision that we may without substantial error adopt it.

The largest part of the skull is that which is at once the receptacle and the protector of the brain, a part which, when unmodified by external pressure, premature synostosis, or other adventitious conditions, owes its form to that of the cerebral hemispheres which it contains. Speaking in this city of George and Andrew Combe, I need not do more than indicate in this matter that observation and experiment have established on a firm basis certain fundamental points regarding the growth of the brain. The study of its development shows that the convolutioning of the cerebral hemisphere is primarily due to the connection, and different rate of growth, of the superficial layer of cells with the underlying layers of white nerve fibres; and that, so far from the shape being seriously modified by the constraining influence of the surrounding embryonic skull, the form of the soft membranous brain-case is primarily moulded upon the brain within it, whose shape it may however be, to some extent a secondary agent in modifying in later growth. We have also learnt that, although in another sense from that of the crude phrenology of Aristotle, Porta, or Gall, the cerebrum is not a single organ acting as a functional unit, but consists of parts, each of which has its specific province; that the increase in the number of cells in any area is correlated with an increase in the size and complexity of pattern of the convolutions of that area; and that this in turn influences the shape of the enclosing shell of membrane and subsequently of bone.

The anatomist and the physiologist have worked hand in hand in the delimitation of these several functional areas, and pathology and surgery have confirmed what experimental physiology has taught. The topography of each part of the cerebrum, so important to the operating surgeon, should be pressed into the service of the anthropologist, whose measurements of the brain-case should have definite relation to these several areas. In the discussion which is to take place on this subject, I hope that some such relationships will be taken account of. This is not the place to work out in detail how this may be done; I only desire to emphasise the fundamental principle of the method.

The second factor which determines the shape of the individual skull is the size of the teeth. That these differ among different races is a matter of common observation; thus the average area of the crowns of the upper-jaw teeth in the male Australian is 1,536 sq. mm., while in the average Englishman it is only 1,286 sq. mm., less than 84 per cent. of that size.[1]

It is easy to understand how natural selection will tend to increase the size of the teeth among those races whose modes of feeding are not aided by the cook or the cutler; and how, on the other hand, the progress of civilised habits, assisted by the craft of the dentist, interferes with the action of selection in this matter among the more cultured races.

For larger teeth a more extensive alveolar arch of implantation is necessary; and as the two jaws are commensurately developed, the lower jaw of the macrodontal races exceeds that of meso- or micro-dontal races in weight. Thus that of a male Australian exceeds that of the average Englishman in the proportion of 100 : 91.

To work this heavier jaw more powerful muscles are needed. In the average well-developed Englishman with perfect teeth the weight of the fleshy portion of the great jaw-muscles, masseters, and temporals is 60 grammes, while the weight of those as ascertained in two Australians was 74 grammes.

Correlated with this greater musculature a sharper definition of the areas for the attachments of the jaw-muscles is required. The muscular fascicles are approxi-

[1] These and the succeeding averages are from my own measurements, taken from never less than ten individual cases.

mately of uniform size in both microdonts and macrodonts, as the range of motion of the jaw differs little in different races; but when the skull is smaller on account of the smaller size of the brain which it contains, the temporal crest ascends higher on the side-wall. In the average Englishman the temporal crests at their points of greatest approximation anteriorly across the brows are 112 mm. apart, but in the Australian they are only separated by 103 mm.: the interstephanic distances in these two are respectively 132 and 114 mm.

The more powerful stroke of the mandibular teeth upon the anvil of the upper-jaw teeth in macrodonts renders necessary a proportionally stronger construction of the bases of support for the upper alveolar arch. In any skull this arch requires to be solidly connected to the wall of the brain-case to which the shock of the impact is ultimately transmitted, and in order to protect from pressure the delicate intervening organs of sight and smell, the connection is accomplished by the reversed arches of the infraorbital margins with their piers, malar and maxillary, founded on the frontal angular processes. These foundations are tied together by the strong supraorbital ridge, so that the whole orbital edge is a ring, made up of the hardest and toughest bone in the skeleton.

A twofold modification of this arrangement is required in the macrodont skull. The bony circum-orbital ring becomes stronger, especially along its lateral piers; and also as the alveolar arch is longer, and consequently projects farther forward, its basis of support must be extended to meet and bear the malar and maxillary piers. But macrodonts are often microcephalic, and therefore the frontal region of the skull must be adjusted to form a foundation for this arch. In the average English male skull, held with its visual axes horizontal, a perpendicular dropped from the anterior surface of the fronto-nasal suture will cut the plane of the alveolar arch between the premolar teeth or through the first premolar. In an Australian skull the perpendicular cuts the horizontal plane at the anterior border of the first molar teeth.

It is obvious, therefore, that to ensure firmness the piers of the arches must be obliquely set; hence the jaw is prognathous; but it is also needful that the supra-orbital arcade should be advanced to meet and bear these piers, as the mandibular stroke is always vertical.

But the inner layer of the skull is moulded on the small frontal lobes of the brain, so this forward extension must affect only the much thicker and tougher outer table of the skull, which, at the period of the second dentition, here separates from the inner table, the interval becoming lined by an extension of the mucosa of the anterior ethmoidal cell. In this way an air-space, the frontal sinus, is formed, whose development is thus directly correlated to the two factors of brain development and size of the teeth. If the frontal lobes are narrow in a macrodont skull, then the foundations of the outer or malar piers of the orbital arch must be extended outwards as well as forwards, the external angular process becoming a prominent abutment at the end of a strong low-browed supraorbital arch, whose overhanging edge gives to the orbital aperture a diminished vertical height.

The crania of the two most macrodont races of mankind, Australian and African, differ in the relation of the jaw to the frontal bone. In the microcephalic Australian the maxillæ are founded upon the under side of the shelf-like projection of the outer table of the frontal, which juts out as a buttress to bear it. On the other hand, the nasal processes of the mesocephalic negro ascend with greater obliquity to abut on the frontal, and have, by their convergence, crushed the nasal bones together, and caused their coalescence and diminution.

The crania of the two most microcephalic races present distinctive features of contrast along the same lines. The Bushman's skull is usually orthognathous, with a straight forehead and a shallow fronto-nasal recess, while the Australian skull is prognathous with heavy overhanging brows. These conditions are correlated to the mesodontism of the Bushman and the macrodontism of the Australian respectively.

In the course of the examination of the relations of brain development to skull growth, some interesting collateral points are elicited. The frontal bone grows from lateral symmetrical centres, which medially coalesce, union taking place

usually between the second and sixth years of age. It has been noticed by anthropologists that metopism, as the anomalous non-union of the halves of this bone has been termed, is rare among microcephalic races, occurring only in about 1 per cent. among Australian skulls. Increased growth of the frontal lobes as the physical accompaniment of increased intellectual activity interposes an obstacle to the easy closure of this median suture, and so in such races as the ancient Egyptian, with a broader forehead, metopism becomes commoner, rising to 7 per cent. In modern civilised races the percentage ranges from 5 to 10. In following out the details of this enumeration, I have spoken as if the microdontal condition had been the primary one, whereas all the available evidence leads to show that the contrary was the case. The characters of all the early crania, Neanderthal, Engis, and Cromagnon, are those of macrodonts. The progress has been from the macrodont to the microdont, as it probably was from the microcephalic to the macrocephalic.

The effects of the variations in size of the teeth are numerous and far-reaching. The fluctuation in the weight of the jaw depending on these variations has an important influence on the centre of gravity of the head, and affects the set of the skull on the vertebral column. This leads to a consequent change in the axes of the occipital condyles, and it is one of the factors which determines the size of the neck-muscles, and therefore the degree of prominence of the nuchal crests and mastoid process.

As the teeth and alveolar arches constitute a part of the apparatus for articulate speech, so these varieties in dental development are not without considerable influence on the nature of the sound produced. The necessarily larger alveolar arch of the macrodont is hypseloid or elliptical, more especially when it has to be supported on a narrow frontal region, and this is associated with a more extensive and flatter palatine surface. This, in turn, alters the shape of the mouth cavity and is associated with a wide flat tongue, whose shape participates in the change of form of the cavity of which it is the floor. The musculature of the tongue varies with its shape, and its motions, upon which articular speech depends, become correspondingly modified. For example, the production of the sharp sibilant 's' requires the approximation of the raised flexible edge of the tongue to the inner margins of the teeth behind the canines, and to the palatine margin close behind the roots of the canine and lateral incisor teeth. This closes the vocal tube laterally, and leaves a small lacuna about 5 mm. wide anteriorly, through which the vibrating current of air is forced. A narrow strip of the palate behind the medial halves of the median incisors bounds this lacuna above, and the slightly concave raised tongue-tip limits it below.

With the macrodont alveolar arch, and the correspondingly modified tongue, sibilation is a difficult feat to accomplish, and hence the sibilant sounds are practically unknown in all the Australian dialects.

It is worthy of note that the five sets of muscular fibres, whose function it is to close laterally the flask-like air-space between the tongue and the palate, are much less distinct and smaller in the tongues of the Australians which I have examined than in the tongues of ordinary Europeans.

There is a wide field open to the anatomical anthropologist in this investigation of the physical basis of dialect. It is one which requires minute and careful work, but it will repay any student who can obtain the material, and who takes time and opportunity to follow it out. The anatomical side of phonology is yet an imperfectly known subject, if one may judge by the crudeness of the descriptions of the mechanism of the several sounds to be found even in the most recent textbooks. As a preliminary step in this direction we are in urgent need of an appropriate nomenclature and an accurate description of the muscular fibres of the tongue. The importance of such a work can be estimated when we remember that there is not one of the 260 possible consonantal sounds known to the phonologist which is not capable of expression in terms of lingual, labial, and palatine musculature.

The acquisition of articulate speech became possible to man only when his alveolar arch and palatine area became shortened and widened, and when his

tongue, by its accommodation to the modified mouth, became shorter and more horizontally flattened, and the higher refinements of pronunciation depend for their production upon more extensive modifications in the same directions.

I can only allude now very briefly to the effects of the third set of factors, the sizes of the sense organs, on the conformation of the skull. We have already noted that the shape and the size of the orbital opening depend on the jaw as much as on the eye. A careful set of measurements has convinced me that the relative or absolute capacity of the orbital cavity is of very little significance as a characteristic of race. The microseme Australian orbit and the megaseme Kanakan are practically of the same capacity, and the eyeballs of the two Australians that I have had the opportunity of examining are a little larger than those of the average of mesoseme Englishmen.

The nasal fossæ are more variable in size than the orbits, but the superficial area of their lining and their capacity are harder to measure, and bear no constant proportion to the size of their apertures, because it is impossible without destroying the skull to shut off the large air sinuses from the nasal fossæ proper for purposes of measurement. Thus the most leptorhine of races, the Esquimaux, with an average nasal index of 437 has a nasal capacity of 55 c.cm., equal to that of the platyrhine Australian, whose average is 54·5, and both exceed the capacity of the leptorhine English, which average about 50 c.cm. There is an intimate and easily proved connection between dental size and the extent of the nasal floor and of the pyriform aperture.

These are but a few of the points which a scientific craniometry should take into consideration. There are many others to which I cannot now refer, but which will naturally occur to the thoughtful anatomist.

In this rapid review of the physical side of our subject the study of these race-characters naturally suggests the vexed question as to the hereditary transmission of acquired peculiarities. This is too large a controversy for us now to engage in, but in the special instances before us there are grounds for the presumption that these characters of microdontism and megacephaly have been acquired at some stage in the ancestral history of humanity, and that they are respectively correlated, with diminution of use in the one case, and increase of activity in the other. It is a matter of observation that these qualities have become hereditary, and the point at issue is not the fact, but the mechanism, of the transmission. We know that use or disuse affects the development of structure in the individual, and it is hard to believe that the persistent disuse of a part through successive generations does not exercise a cumulative influence on its ultimate condition.

There is a statement in reference to one of these characters which has gained an entrance into the text-books, to the effect that the human alveolar arch is shortening, and that the last molar tooth is being crowded out of existence. I have examined 400 crania of men of the long and round-barrow races, Romano-British and early Saxon, and have not found among all these a single instance of absence of the third molar or of overcrowded teeth. On the other hand, out of 200 ancient Egyptian skulls 9 per cent. showed displacement or disease, and 1½ per cent. showed the want of one molar tooth. Out of 200 modern English skulls there was no third molar tooth in 1 per cent. So far this seems to confirm the current opinion.

Yet the whole history of the organism bears testimony to the marvellous persistence of parts in spite of contumely and disuse. Take, for example, the present position of the little toe in man. We know not the condition of this digit in prehistoric man, and have but little information as to its state among savage tribes at the present day; but we do know that in civilised peoples, whose feet are from infancy subjected to conditions of restraint, it is an imperfect organ—

> Of every function shorn
> Except to act as basis for a corn.

In 1 per cent. of adults the second and third joints have ankylosed; in 3 per cent. the joint between them is rudimentary, with scarcely a trace of a cavity; in

20 per cent. of feet the organ has lost one or more of its normal complement of muscles. But though shorn of some of its elements, and with others as mere shreds, the toe persists, and he would be a bold prophet who would venture to forecast how many generations of booted ancestry would suffice to eliminate it from the organisation of the normal man.

Nevertheless, although it is difficult to demonstrate, in the present imperfect state of knowledge, the method whereby race-characters have originated, I think that the most of our anthropologists at least covertly adopt the philosophy of the ancient proverb, 'The fathers have eaten sour grapes and the children's teeth are set on edge.'

But there are other branches of anthropology of far greater interest than these simple problems upon which we have tarried so long. The study of man's intellectual nature is equally a part of our subject, and the outcomes of that nature are to be traced in the tripartite record of human progress which we call the history of culture. It is ours to trace the progress of man's inventions and their fruits in language and the arts, the direct products of the human mind. It is also ours to follow the history of man's discovery of those secrets of nature to the unfolding of which we give the name of science. The task is also ours to inquire into that largest and most important of all sections of the history of culture which deals with the relation of human life to the unseen world, and to disentangle out of the complex network of religion, mythology, and ritual those elements which are real truths, either discovered by the exercise of man's reason, or learnt by him in ways whereof science takes no account, from those adventitious and invented products of human fear and fancy which obscure the view of the central realities. In this country it matters less that our time forbids us to wander in these fascinating fields wherein the anthropologist loves to linger, as the munificent benefaction of Lord Gifford has ensured that there shall be an annual fourfold presentation of the subject before the students of our Scottish universities. There is no fear that interest in these questions will flag for want of diversity in the method of treatment or of varieties in the standpoints of the successive Gifford lecturers.

From the ground of our present knowledge we can but faintly forecast the future of anthropology, when its range is extended by further research, and when it is purged of fancies, false analogies, and imperfect observations. It may be that there is in store for us a clearer view of the past history of man, of the place and time of his first appearance, of his primitive character, and of his progress. But has this knowledge, interesting as it may be for its own sake, any bearing on the future of mankind? Hitherto growth in knowledge has not been accompanied with a commensurate increase in the sum of human happiness, but this is probably due to the imperfection which characterises even our most advanced attainments. For example, while the medical and sanitary sciences, by their progress, are diminishing the dangers which beset humanity, they have also been the means of preserving and permitting the perpetuation of the weaklings of the race, which, had natural selection exercised its unhindered sway, would have been crushed out of existence in the struggle for life.

It is, however, of the essence of true scientific knowledge, when perfected, that it enables us to predict, and if we ever rise to the possession of a true appreciation of the influences which have affected mankind in the past, we should endeavour to learn how to direct these influences in the future that they shall work for the progress of the race. With such a knowledge we shall be able to advance in that practical branch of anthropology, the science of education; and so to guide and foster the physical, intellectual, and moral growth of the individual that he will be enabled to exercise all his powers in the best possible directions. And, lastly, we shall make progress in that kindred department, sociology, the study of which does for the community what the science of education does for the individual. Is it a dream that the future has in store for us such an anthropological Utopia?

The following Papers and Reports were read :—

1. *On the Organisation of Local Anthropological Research.*
By E. W. Brabrook.

The writer has been authorised by a joint committee of delegates from the Society of Antiquaries, the Folklore Society, and the Anthropological Institute to communicate to the Section a plan for an ethnographical survey of the United Kingdom, by which observations should be made simultaneously in selected localities on the ancient remains, the local customs, and the physical characters of the people. The delegates would largely rely for assistance in carrying out this scheme upon the corresponding societies of the British Association, and an analysis of the two hundred or more papers published by such societies in connection with the subjects of Section H recorded during the last seven years shows that as many as twenty-nine local societies have been engaged in valuable original anthropological work. These and other societies, as well as those in union with the Society of Antiquaries, would doubtless be willing to act upon a uniform plan. As materials for the formation of such a plan of action the writer refers to Mr. Payne's archæological survey of the county of Kent, and to those of other counties which have already been completed on the same model; to the collection of Gloucestershire Folklore and the 'Handbook of Folklore,' published by the Folklore Society; and to the second edition of 'Notes and Queries on Anthropology,' just completed by the Anthropological Institute. He also refers to the reports of the Anthropometric Committee, and especially to the scheme for collection of photographs, in respect of which Mr. Galton has favoured him with some practical suggestions. All these will have to be reduced by the delegates to a brief and simple code of instructions. The matter is one that will not brook undue delay, as the evidence is fast slipping out of our grasp.

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2. *Report of the Anthropometric Laboratory Committee.*
See Reports, p. 618.

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3. *Report of the Anthropological Notes and Queries Committee.*
See Reports, p. 537.

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4. *Discovery of the Common Occurrence of Palæolithic Weapons in Scotland.*
By Rev. Frederick Smith.

The author shows that the opinion of scientific men, with regard to the question of the occurrence of the relics of Palæolithic man in Scotland, is down to the present time of a negative character. It is pretty confidently asserted that north of a line across the Lower Middle of England 'implement-bearing strata' do not occur.

But from an inspection in 1883 of the alluvial deposits of the South of England and North-east France, as well as in a part of the Rhine Valley, he was led to infer that it was well-nigh impossible that Palæolithic man could have been shut out of Scotland during the enormous lapse of time represented by the implement-yielding strata of the south. This conclusion was based also upon the result of eleven years' observations upon rivers and river phenomena made previous to 1883 in the valleys of Scotland; and on his return north in that year he determined to put to proof the negative opinions regarding this question. This quest has been prosecuted now for nine years, with, in the face of general opinion, extraordinarily affirmative results.

He has made systematic research in the soils, with the striking result that in the neighbourhood of Perth certain angular stones occur commonly in the soils of certain areas, and are entirely absent from others.

He has made patient and long-continued search in modern and ancient gravel beds, in the beds of existing rivers, in 'Kame' deposits, and finally in certain phases of boulder clay; and he finds that each piece of research yielded some corroborative evidence, but that the boulder clay—*i.e.*, certain characteristic portions—yield abundant evidence, in the shape of glaciated, broken, and crushed specimens of the weapons of Palæolithic man. He believes them to be as common in certain ancient soils, and in these certain phases of the boulder clay in Scotland, as they are in any areas or deposits in England or France.

The material in which the weapons mainly occur represents ancient river-accumulated beds, exact equivalents of those of the Ouse and Thames and Somme Valleys, which are characterised by their weapons, and remains of extinct mammalia; and they were formed in exactly identical circumstances during a long period of time, *terminated in the north by an inception of glaciers*, which did not affect such valleys as now contain undisturbed implement- and bone-bearing strata. Remains of the mammoth and other extinct forms have been found in the north, but the ponderous steps of glaciers down the valleys of mountainous England and Scotland cannot have left many recognisable osseous remains.

The actual tangible results of the author's years of research are the best proof of his success in what he undertook to prove. He has collected at least 350 specimens, which he believes to be definite evidence of the long-continued sojourn of Palæolithic man north of the Border; the large majority of these specimens he proposed to exhibit at the Association's meetings in Edinburgh; many of the specimens in this collection he considers as characteristic and unassailable as any from Southern England or France.

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5. *Notes on Cyclopean Architecture in the South Pacific Islands.*

By R. A. Sterndale.

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6. *On a Fronto-limbic Formation of the Human Cerebrum.*

By Dr. L. Manouvrier, *Professor at the School of Anthropology, Paris.*

I. Exposition des Faits.

1°. Quand la première circonvolution frontale est doublée longitudinalement, la circonvolution du corps calleux reste presque toujours simple, mais d'autant plus mince ou étroite que la frontale interne est plus développée en largeur.

Il existe un véritable balancement entre les deux circonvolutions sous le rapport de la largeur.

2°. Quand la frontale interne n'est pas double longitudinalement et lorsqu'elle est en outre peu large, alors apparaît très souvent sur les cerveaux humains bien développés un sillon longitudinal dans l'épaisseur de la circonvolution du corps calleux. Ce sillon, que l'on ne trouve pas chez les anthropoïdes, mais qui existe chez divers herbivores à titre de complication limbique, réapparaît chez l'homme comme formation frontale supplémentaire.

Il peut arriver que ce sillon acquiert un développement tel qu'il a été parfois confondu avec la grande scissure sous-frontale de Broca, et que celle-ci a pu être décrite sur certains cerveaux comme étant un simple sillon de dédoublement de la circonvolution frontale interne.

C'est en étudiant le cerveau d'un homme très distingué (Eugène Véron) que M. Manouvrier a pu saisir, en voie de réalisation, cette substitution d'un sillon néo-sous-frontal à la scissure sous-frontale classique. Il en a observé les divers degrés de développement sur une série de cerveaux, et a pu ainsi montrer, sur le cerveau du Professeur Adolphe Bertillon la réalisation complète de la disposition morphologique qu'il décrit.

II. Interprétation de ces Faits.

M. Manouvrier attire d'abord l'attention sur le fait qu'il s'agit là de véritables compensations au profit du lobe frontal.

Il rappelle ensuite que Broca a montré l'homologie de la circonvolution du corps calleux (*gyrus fornicatus*) avec une partie du grand lobe limbique et sa diminution graduelle dans la série des mammifères au profit des lobes cérébraux adjacents, et plus spécialement chez l'homme au profit du lobe frontal.

Il considère donc la formation fronto-limbique décrite ci-dessus comme indiquant, dans l'éspèce humaine, la phase la plus récente de l'empiètement du lobe frontal sur le grand lobe limbique, et comme indiquant une véritable fusion, probablement physiologique aussi bien que morphologique, entre ces deux lobes, très vraisemblablement dans le sens d'un perfectionnement frontal et intellectuel.

Il a constaté le progrès en question du lobe frontal sur tous les cerveaux d'hommes plus au moins célèbres ou distingués qu'il a pu examiner à Paris. Mais il ajoute que les faits sur lesquels il vient d'attirer l'attention sont extrêmement fréquents et ne sont pas rares même chez les nègres.

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7. *The Indo-Europeans' Conception of a Future Life and its Bearing upon their Religions.* *By* Professor G. Hartwell Jones, *M.A.*

In a previous paper read in 1891, 'The Barbaric Elements in Ancient Greece and Italy,' the view was propounded that (*a*) the Classics were of deep scientific interest; (*b*) the level of culture among the early Greeks and Italians was low; (*c*) their culture dated from contact with the East; (*d*) the criteria must be sought in archæology, in its widest sense, as much as in the science of language.

This monograph deals with a section of the above subject, which will, in its turn, throw light upon ethnology; only by division of labour and unbiassed research can truth be reached in mythology; here the crudest notions of these people are discussed. The belief in a future life which is, as Lessing and Schopenhauer have said, an integral portion of religion, is deeply rooted and a common inheritance of Indo-Europeans, but the richer the endowments of the race the nobler its aspirations after immortality. It has been stated by Peschel that some negro tribes have no such idea, but then they would equally doubt their present existence. The doctrine in some countries was gradually transformed or degenerated.

The different opinions regarding immortality in vogue to-day are not new, for even as early as the Vedic hymns are found—

(1) *Deathlessness in thought, in children.*—This idea is frequently found in Greece, and the survival in posterity is a prominent feature of Roman thought. This, however, does not fall within the scope of the present inquiry.

(2) *An actual life beyond the grave* possessed peculiar attractions for Indo-European races, though they are not agreed upon the sphere in which the disembodied spirit lived, some looking for it on earth, others in heaven.

Three heads naturally suggest themselves :—

I. *The connection of body and soul.*
II. *The condition of the deceased.*
III. *The relations between the departed and those left behind.*

I.

The nature of the soul.—In primitive times souls are ascribed to the universe—the *anima mundi*—to nymphs of various kinds, to the lower animals, to fountains, or trees. Heaven is the *source* from which the soul of man is derived, and to which it returns after purification. As to its *creation*, it has no corporeal element, it was created before the body; sometimes it is identified with fire. The etymology of the *expressions* for soul are instructive, *e.g.*, Sanskrit *atīndriya*, or 'transcending the senses'; Greek *θυμός*, from a root meaning to agitate; so too

the notion of 'air,' 'vapour,' 'shade.' Still more common is the idea of 'breath.' Its *seat* is the heart or blood.

The way in which death was regarded.—At the moment of dissolution, the soul escapes through the mouth or nostrils; it leaves with a groan; it passes to the ethereal regions. Death is often looked upon as a kind of sleep. Their *stoicism* in the face of death is attested by the frequency of suicide, or of substitution, or the prohibition of mourning. This was because, *e.g.*, of the dread of decrepitude, assurance of the preservation of the family, frailty of life, and confident hope of a life to come. Yet, early language is rich in *euphemistic* terms, *e.g.*, to die is 'to be missing,' 'to depart,' and the Goddess of Fate is 'The Sparing One.'

II.

The character of the spirit-world.—The theory of a future life prevalent in the animistic stage is that of *continuance*, the tastes and occupations being the same as in this world, *e.g.*, even Homer has not outgrown this. But this existence is incomplete and dreary; the ghosts gibber and are doomed to silence.

The influence of this idea upon ritual and belief.—The severance was not complete, for the welfare of the spirit depended upon the proper treatment of the body; else it wandered disconsolate. (This notion is a leading feature of Indo-European mythology.) (*a*) Hence the observance of *rites*. At first the body was disposed of by *inhumation*, probably to preserve the identity of the deceased, but in certain conditions of life, *e.g.*, during war or the chase, *cremation* was employed. At least a handful of dust had to be sprinkled over the corpse before the spirit could obtain repose; its neglect was regarded with horror. The same motive dictated the rearing of *cenotaphs*.

(*b*) The *tomb* was constructed on the model of the house; this custom is not confined to 'Turanians.'

(*c*) The deceased was furnished with all necessaries for his new home, attendants and wives, dogs and horses, weapons, clothing, and earthenware.

The abode of the dead.—(*a*) The earliest theory is that the soul became *ethereal*, passing into the wind, or fire, or constellations.

(*β*) A region somewhere *upon earth*. The exact locality was uncertain, because of the nebulous character of their life, for they followed certain Great Spirits. Then the region of *bliss* was placed in the West.

The influence of surroundings is noteworthy here; thus, to the æsthetic mind of the Greek such a monotonous existence was repulsive, but it is not likely that this was the original conception. At a later period an attempt was made to combine these worlds.

The germs of a theory of *recompense and punishment* are found early, *e.g.*, Φλεγύαι may be equated with the Indian *Bhrigu* (Weber) and Τάρταρος with *talâtala* (Benfey). No doubt the idea gained in clearness when they came into contact with the Semites. *Transmigration*, *regeneration*, and *purification* belong to a later time.

III.

The relation between the living and the departed.—In addition to the care taken at *burial*, there was constant communication, *e.g.*, in *dreams*. Hence the respect shown to (1) *kindly* spirits, like the *pitaras*, *fravashi*, *manes*, &c.—the givers of wealth; (2) the *evil-disposed*, like the *lemures* or *larvæ*. This gave rise to *ancestral worship*, and is connected with the sustentation of the family; children were buried under the eaves of houses, and did not need propitiation. Thus the worshippers were actuated by (1) *fear*, (2) *sympathy*.

FRIDAY, AUGUST 5.

The following Papers and Reports were read:—

1. *Exhibition of Photographs, Weapons, &c., of Toba Indians of the Gran Chaco.* *By* J. GRAHAM KERR.

The specimens exhibited had been obtained from a tribe of the Tobas on the banks of the Rio Pilcomayo. Amongst weapons the chief were bows and arrows, the former being noteworthy from their reinforcement by a backstring. The arrows were of cane with long wooden points made of cascarandá. An arrow with an iron head was also shown, the head being formed of fencing wire beaten out. Other weapons shown were a club made of cascarandá and a short and highly artistic lance of the same material. Amongst other implements was exhibited a Toba fire-drill; the method of using it was explained: also several examples of the textile productions of the Tobas and a rude sketch of the human figure as drawn by a Toba chief.

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2. *Exhibition of pre-Palæolithic Flints.* *By* J. MONTGOMERIE BELL.

On the heights of the North Downs of Kent, at an altitude of from 600 to 750 feet, a large series of flints has in the past few years been collected, chiefly by Mr. Benjamin Harrison, of Ightham, who first directed attention to them, as possessing signs of human handiwork. These flints, if accepted as the work of man, possess a peculiar interest, as their age is undoubtedly very great, and their general style represents an early stage in human culture. In age they are plainly anterior to the River-valleys, because they are found in patches of old gravel-beds which lie upon the uneroded plateaus between the valleys which slope northward to the Thames. These valleys belong to the Palæolithic or River-valley age; but the valleys are eroded out of the plateaus, which form the relics of an older surface, and may in popular speech be named pre-Palæolithic.

The peculiarity of the flints exhibited is that they are not shaped into particular forms by the will and skill of the workman as Palæolithic flints are. They are simply stones taken from the ground, and used almost in the state in which they are picked up, only the edges are altered; they are chipped flints rather than shaped flints, used tools not made tools. Historically we have relics of such a stage in the stones used by the Bushmen and by the Tasmanian, and it is probable that such a stage was general in human history. The difficulty in identifying flints of this class as having actually been human implements is that they are neither flaked nor bulbed: these, the hall-marks of flint work, are absent; they have only the marks of use. Hence some authorities have accepted them, and others have rejected them. The writer gave the reasons which had convinced him of their authenticity, namely, that the chipping is regular and purpose-like, such as nature is not likely to have hit upon; it is sometimes within a hollow curve, where natural agencies could not act; the edges of many unbulbed flints have far more regular marks of wear, which is the true indication of use by man that many bulbed flakes possess, whose edges have undoubtedly been used; and lastly, there is a sequence in the types which leads into the types of the River-valley period: this is especially visible in a series of pear-shaped flints with chipped edges similar to, and almost identical in form with, the pear-shaped hâche of St. Acheul.

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3. *The Present Inhabitants of Mashonaland, and their Origin.* *By* J. THEODORE BENT.

The recognised name Makalanga, and its connection with the Portuguese name for the Monomatapa people, and further identification of names as given by Bocarro and the traces left of Monomatapa towns and villages, are discussed in the paper.

The Portuguese writer Dos Santos describes the people of Monomatapa much as they are to-day.

Origin of the Makalangas much more obscure, but references to them adduced from early Arabian writers prove beyond doubt that a similar people inhabited this country 1,000 years ago.

Customs are still inherent in the race, pointing to external influence. The dynastic names of the chiefs, the succession to the chiefdoms.

The totems of the Makalangas.

Their religion and monotheistic tendency, sacrifice to ancestors, and sacrifice of goats to ward off calamities.

The burial of their dead.

The day of rest during the ploughing season, co-operative labours, circumcision, and reference to points which connect them with an Asiatic or northern origin.

Similar instances produced from private life. The pillows or head-rests. The calculating game of *is ufuba*. The beer they drink—the chief and headmen drink first. The thick milk or *mast*. The Mashona piano. The *strigil*—iron sceptre of chief—and iron smelting.

Arab type of countenance and refinement of manner.

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4. *The Report of the Mashonaland Committee.*—See Reports, p. 538.

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5. *On the Value of Art in Ethnology. By* Professor A. C. Haddon.

In order to study such an intricate subject as decorative art from the point of view of the biologist, it is necessary first to confine one's attention to savage art, where the problems are presented in a simpler form. In taking a definite area into consideration, such as British New Guinea, it is found that there are several distinct and well-defined artistic provinces. The Torres Straits district is characterised by the prevalence of straight and angled lines, to the exclusion of curved lines, and the representation of animal forms, the latter being associated with totemism. In the Gulf district the human face and form are the basis of almost all their art. In the Port Moresby district decoration is in the form of panels, and mainly straight and angled lines; whereas in the South Cape and Archipelago district there is a wonderful richness of design, in which curved lines are abundant. It is well known that in this latter district there has been a great mixture of race. It would appear that homogeneous peoples have a uniform style in their art, but that race mixture tends to varied artistic treatment. It is an established dictum in biology that all life comes from pre-existing life, so we may assert for savage art, and possibly for that of more civilised peoples, that all artistic designs arise from, or are suggested by, natural objects. Savages do not invent or create patterns or schemes of ornamentation; the latter are arrived at by a kind of almost undirected evolution.

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6. *Similarity of Certain Ancient Necropoleis in the Pyrenees and in North Britain. By* Dr. Phené, *F.S.A.*

In the personal surveys and investigations made by the author in Western Europe tradition was often the beacon which led to the most interesting discoveries. The tradition of St. Patrick driving the serpents, not of Ireland, as popularly now expressed, but of Sligo into the Atlantic, whence they returned to Donegal, led to the examination of ancient relics very similar to those existing in the Pyrenees and in several parts of England and Scotland, which have been rendered classical by the Arthurian legends, which legends evidently had existence in those localities long prior to the age of the historical Arthur. In the present case the author selected Luchon, a spot where the traditions of the Pyrenees are most concentrated, and where remarkable customs have been till very lately

practised, which locality abounds with interments of a peculiar kind more or less surrounding a great central mound, serpentine in form, the head of which, evidently formerly constructed with a *souterrain* chamber, has been cut away, and in the cavity a small church erected in its place. The walls of this antique little church are covered with votive tablets of early Christian and Pagan Roman times; the exhumations from the more lofty curvature of the mound, which exhibited depositions of chronological sequence, in which earlier successive interments of relics and cinerary remains appear always to have been respected by subsequent depositors, as shown from the undisturbed relics of earlier date (now to a great extent in a local museum), which go back through successive stages of varied national occupation from Roman to early Keltic and even less determinable ancient times, the relics of which consist of rude pottery and flint chippings. Strange rites are still celebrated on the mound and in the surrounding districts by processions with banners and chanting, and the locally surrounding interments are so arranged that the position of the various very ancient tombs, which are small Kist vaens, sometimes only a foot square with cinerary matter covered by single stones of rude and insignificant appearance, are frequently an imitation of the sinuosities of the great mound which contained the successive layers of relics so recovered. The mound appears to a great extent artificial. In his researches in the Pyrenees the author was assisted by two well-known antiquaries, and who certified to the remarkable facts. Almost all the above features have been discovered by the author in certain localities of Somersetshire, Bedfordshire, Argyllshire, and elsewhere. When the author read his first paper on such mounds before the British Association in Edinburgh in 1871 he had then made no exhumations from any such mounds. The great mound, to which his first paper referred, is formed of a natural deposit cut into shape, the excised portions being close at hand: it had a chamber in the centre of the head made of large blocks of granite, and containing a great quantity of burnt bones, wood, and hazel-nuts. It appeared not to have been disturbed, and a flint or chalcedony instrument delicately serrated was found. This mound also, as well as one in the locality referred to in Ireland, and that in the Pyrenees, are distinctly serpentine in form. A large surrounding area is occupied by grand cairns varying from ten to sixty feet in diameter; they are arranged like the chambers of interment in the Pyrenees in a serpentine form, apparently repeating the form of the great mound. The interiors of these cairns also, in each case, contain sepulchral chambers or Kist vaens.

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7. *A Contribution to the Ethnology of Jersey.* *By* Andrew Dunlop, *M.D., F.G.S.*

The author has examined 239 living persons out of a possible 54,000, choosing invariably those which could be ascertained to be pure descendants of the oldest established families in the island. The following is the result of the investigation as to the colour of eyes and hair in percentages:—

Eyes	Hair					Total
	Yellow	Light Brown	Brown	Dark Brown	Black	
Blue or grey .	0·40	11·29	20·50	15·06	2·09	49·34
Mixed . .	0·00	1·25	11·39	10·04	3·70	26·38
Dark . .	0·00	0·83	5·40	12·97	5·02	24·22
Total . .	0·40	13·37	37·29	38·07	10·81	99·94

The author compared his figures with those of Dr. Beddoe, and pointed out that, as he feared many of his 'mixed eyes' would be considered dark eyes by Dr. Beddoe, and light brown hair as brown hair by Dr. Beddoe, the proportion of

dark eyes would appear lower, and of fair hair higher, in Jersey than they most probably would do under the doctor's system of classification. Red-haired persons are not numerous in Jersey. The average cephalic index of the 239 persons was 80·5 (the lowest 67·8, and the highest 87·5), equal to Broca's mesaticephalic class. The average height of the 110 males measured was 5 feet 7½ inches, but the figures of height were not considered reliable.

The author concluded that the blood of the Jersey people is largely derived from the old Celtic aboriginal stock, resembling the populations of the Celtic districts of France and Britain, the Teutonic or Scandinavian admixture not being large.

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8. *On the Past and Present Condition of the Natives of the Friendly Islands, or Tonga.* *By* R. B. Leefe.

The author pointed out that there is no inflection of the verb word in its conjugation, the tenses and persons being expressed by means of prefixes. Many English words are incorporated with the language; every word ends in a vowel, and while two vowels may come together this is not allowable with consonants. The number of pronouns is large; a dual and plural, inclusive and exclusive, of the person addressed exist. The prefix *faka-* turns the noun into an adjective.

The natives are purely agriculturists and fishermen, and on one atoll have a distinct species of fish upon which they feed.

The author complained much of the government introduced by the missionaries as being one calculated to lessen the happiness of the people to the profit of Manchester manufacturers; for instance, one of the first new laws introduced was one enforcing the covering of the body above the waist as well as below.

Much time is wasted on the laborious manufacture of tupa cloth, which is marked with devices to show from what town it emanates. The making of copra (dried cocoanut) is also a settled occupation of the people. Canoe building, once an art, is fast disappearing, and 'in this, as in truthfulness, honesty, and morality, civilisation is fast doing its work, and spoiling one of the originally finest races under the sun.'

The natives still cook in their earth-ovens. The nets are now usually of European twine, instead of the native fibre *aka*. To obtain fish by poisoning the water is a common method.

The building of the houses, which is said to have much deteriorated since European intercourse, is still above the level of that of most Pacific islanders. Scientifically their plan is faultless, strength being afforded where the greatest strain comes, and the houses can only be levelled by fire or hurricane, no nails being used, but instead thereof the beams, &c., are fastened with cocoanut husk, and hence their elasticity.

The women are well cared for, and, with the exception of the arduous manufacture of the native cloth, have an easy time. In the question of dress and morality the author condemned the views of the missionaries. Love, in our sense of the word, ending in lasting friendship, is unknown to the natives. The population is fast diminishing in numbers.

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9. *Damma Island and its Natives.*
By P. W. Bassett-Smith, *Surg. R.N., F.R.M.S.*

Damma Island is the largest of the Serwati group, in the Banda Sea, and is under Dutch protection. As far as the author was able to make out, there were two more or less distinct types of people. The first with dark brown skins, coarse black hair, either straight or with a tendency to curl, sometimes closely cut; roundish faces and heads, dark eyes, high cheekbones, nose much sunken at the base, nostrils dilated, mouth rather large, and lips much misshapen by betel chewing, the bolus of which they kept half protruding in a disgusting way; body with but little hair, occasionally a short wiry beard and whiskers; height about 5 ft. 6 in.,

limbs well formed, ankles and wrists not particularly small, expression quiet and rather dull.

The second a coppery brown, much lighter race, with strong frizzly hair, either cut short or standing out in a mop, coloured a rich orange yellow with lime, and evidently a great source of pride to them; face oval, eyes dark, sparkling, and full of life; nose aquiline, often slightly hooked at the tip, nostrils wide; mouth small, lips well cut, no hair on the face, at least not when young adults, teeth good; expression bright and intelligent, limbs well shaped, rather delicate wrists and ankles, average height 5 feet 5 inches or under. Some of these were so graceful and handsome as to fill anyone who observed them with admiration; it was not a single individual, but many; and one instinctively made friends.

The first type we found mostly in the coast villages, the other on the hill side. There was also a mixture between these two types, Malays and Papuans. The women were shorter in stature, with their hair done up in a knot at the back of the head. When young they were pleasant to look at, but apparently soon aged, and with their very pendent breasts were ugly.

The average measurements of the hillmen were:—Height 5 feet 5 inches, length of head $7\frac{4}{16}$ inches, width of head 6 inches, cephalic index 82, length of arm 32 inches, and of leg 35 inches.

Their numerals are:—

1	sarrah	4	worwart	7	worit	10	woosarrah
2	wooruh	5	woolim	8	wortu	11	„ missa
3	wortel	6	wornam	9	worsi	12	„ wooruh
20	woo worrah					31	woo wortel missa
30	woo wortel					40	woo worwart

man *oomoo* fire *ai*
woman *hatu* water *manu*

They use bamboo bows and arrows, the latter *not* feathered and more or less barbed. They wear curious combs, and from their ear lobes greatly extended hang silver, tortoise-shell, blackwood, or fish-bone pendants; they wear wood or bone bracelets much too small for Europeans. They have a curious ceremony of drum beating morn and night, and their dancing is of a monotonous character, there being a sort of recitative and two choruses ending by *kāki* and *sāli*, which are uttered with the full force of the lungs.

The canoes are dug-outs. Salt is obtained by evaporating sea water by the heat of the sun in shallow trays made of palm leaves.

The natives reminded the author of the people of Tenimber, described by H. O. Forbes.

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10. *Report of the North-western Tribes of Canada Committee.*
See Reports, p. 545.

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11. *A Discussion on Anthropometric Identification was opened by* Dr. L. Manouvrier, *of Paris.*

SATURDAY, AUGUST 6.

A Discussion on Criminal Anthropology took place after the reading of the following Paper:—

Some Developmental and Evolutional Aspects of Criminal Anthropology.
By T. S. Clouston, *M.D., F.R.S.E.*

The work done in criminal anthropology in this and other countries was first reviewed, and the failure of the workers to agree on any anatomical, physiological,

or psychological data for establishing a criminal type was pointed out. But the author said that one conclusion was forced upon him. If there was not an absolutely marked criminal type all would agree that criminals fell far below a high anatomical and physiological standard of brain, body, and mind. The weak point in criminal anthropology was that while criminals had been weighed, measured, observed, and described, the classes of society from which most of them came, but who had not been convicted of breaking the law, had not been observed in the same way, and had not had the same scientific tests applied to them. There was little use in gauging the criminal by the standard of the well-fed, the respectable, and the comfortable classes of society. The scientific method would be to apply the test to whole sections of the lower labouring classes of society, including the criminals. There was a large class of human beings whose brains suffered manifestly from arrested development of normal function. This existed in any and every degree, and might extend to any and every mental and moral faculty. A human being only slightly imbecile in mind had many anatomical and psychological resemblances to the criminal. Scientific anthropology that covered the whole ground must deal with the idle, the vagrant, the pauper, the prostitute, the drunkard, the imbecile, the epileptic, and the insane, as well as the criminal and the class to which he usually belonged. If inquiry established physical, hereditary, and psychological bases of criminality, the State would have to treat the criminal from a point of view entirely different from the punitive method. Such was the contention of the modern school of that department of study. One physiological aspect of the question had not obtained the observation it was worthy of, and that was the developmental aspect, nor had the evolutional aspect had sufficient attention paid to it. Many were criminals because their brains were the same as those of their ancestors, and their environment had changed only in the present generation. In some districts of the country there were actually no criminals, yet when some of the people of those districts went to live in great cities they became habitual criminals. The too sudden exposure to new environments and conditions, with the necessary attempts at adaptation to those environments, was one of the great factors of criminality and of certain forms of insanity. The later years of adolescence were those in which the great inhibitory moral and social faculties that fit men to live in a well-ordered civil modern society attain such perfection as they are capable of, and it is during this period that most of our criminals become such. It is in the early years of adolescence that epilepsy arises in the greatest degree, and in the later years that 'adolescent insanity,' hysteria, dipsomania, asthma, phthisis, and other developmental diseases of the mental, motor, or nutritive functions arise. Criminality in certain cases seems to class itself among such developmental defects. The essential likeness of the epileptic and the criminal brain is one of the most striking of Dr. Benedikt's observations. What are to the doctor symptoms of diseases are to the policeman and the magistrate proofs of criminality. In the rich family the doctor looked after the case; in the poor family the policeman and the gaoler. Yet both cases were equally phases of brain development due to hereditary weakness. A deformity in the hard palate which became high in the centre and V-shaped he found to exist in 35 per cent. of criminals, 37 per cent. of epileptics, 55 per cent. of the adolescent insane, and 61 per cent. of idiots and imbeciles, as compared with 19 per cent. of the general population, and the hard palate has a close relationship to the base of the anterior lobes of the brain in man, those lobes being closely related to the mental functions. He had seen and studied many cases of crime or vice in which moral responsibility did not exist. All considerations pointed to two great sources of criminality. The first was the not fully evolved man who was fitted to do his work in a primitive society, but who could not accommodate himself to the conditions of a life of a highly organised and extremely artificial modern society, and who fell into criminality and swelled the list through his environment. The second was the pathologically non-developed man, whose development had been arrested towards the end of the period of adolescence before his inhibitory and moral qualities had attained their full strength.

MONDAY, AUGUST 8.

The following Papers were read:—

1. *On a Coiffure from the South Seas.* *By* Sir W. Turner.

Sir William Turner exhibited the coiffure of a Kanaka labourer, who had been employed on a sugar plantation in Queensland. The mode of dressing the hair in locks, each of which was tied round with a slender ribbon, half a millimetre in width, formed of vegetable fibre, was described. The free end of each lock was not confined by the ribbon, and the hair was curly at this end, and somewhat auburn-tinted; probably it had been artificially bleached: 834 such locks were present in the coiffure, and it was estimated that about 120 hairs were in each lock, making in all about 100,000 hairs in the coiffure. The locks were tied together into a bunch with bands of tape, so that the coiffure had projected upwards for 17 inches from the top of the head in the manner figured by Dr. Prichard, in vol. ii. of the 'Natural History of Man,' in a native of Ombai Island. Captain Cook, in vol. ii. p. 78 of his 'Voyages,' figures a man of the island of Tanna in whom a similar mode of dressing the hair is described, but in this case the locks were not tied together into a top-knot, but hung pendulous over the neck and shoulders.

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2. *On the Articular Processes of the Vertebræ in the Gorilla compared with those in Man, and on Costo-vertebral Variation in the Gorilla.* *By* Professor Struthers, *M.D., LL.D.*

The paper was founded on the observation of twenty gorilla skeletons, two of which—a male and a female—the author exhibited to the Section. In the female specimen the ribs are placed on the spine a vertebra lower than usual, giving eight cervical vertebræ. That vertebra has the usual characters of the normal seventh, including the foramen in the transverse process. The thirteenth rib is well formed; three lumbar vertebræ, the last (twenty-fourth vertebra) not ossified to the sacrum. It is an old gorilla, the sacro-iliac joint on one side ossified. In three of the twenty gorillas there were fourteen ribs instead of the usual thirteen. In man an additional rib occurs more frequently at the neck than below. In the gorilla it would seem to be the contrary. The lowest rib in man is small and variable; in the gorilla the lowest rib is long.

Articular processes are adapted to the different movements of the several regions of the vertebral column. The early type, seen throughout the vertebral column in reptiles and birds, is retained in the lumbar region of mammals—the anterior pair form the zygantrum, the posterior pair the zygosphene. The place of change to the dorsal type is generally at several vertebræ in front of the last rib. In man it is normally just above the last rib. In the gorilla the change occurs generally a vertebra lower, which is just above its last rib. The place varies sometimes both in man and in the gorilla, tending to follow any variation in the number or position of the ribs.

Approximation of the lumbar articular processes, going downwards, does not occur in the female gorilla until the lumbo-sacral joint is reached. In the male exhibited to the Section the approximation is seen on all the four lumbar vertebræ, but all male gorillas do not show this until the last two vertebræ are reached. This approximation of the lumbar articular processes, going downwards, in the gorilla contrasts strongly with the opposite condition in man, in whom the width apart of the processes increases from the third vertebra downwards, and is very marked above and below the last vertebra, though not invariably below it.

The lowest lumbar vertebra (twenty-fourth vertebra) is known to be frequently ossified to the sacrum in the gorilla, at least in old males. The author has found this union to have taken place in eight of the cases—seven males and one female—and not to have occurred in twelve—eight males and four females. But three of the twelve—two males and one female—were not adult. In man the tendency

rather is to increase the number of free vertebræ in the lumbar region by detachment of the upper sacral vertebra. The differences alluded to have reference mainly to the great freedom of the lumbar region in man compared with that in the gorilla, and to the greater thoracic development in the gorilla.

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3. *On the Probable Derivation of some Characteristic Sounds in Certain Languages from Cries or Noises made by Animals.* *By* J. Mansel Weale.

The author relates how he first noticed the resemblance between the lullaby of a native voer-looper and the croaking of frogs at Boomplatz, Orange River Free State. Later he was often puzzled in Kaffraria by the resemblance between the sounds of distant Kafir dance-music and that made by the frogs in vleys or ponds. He attempted to analyse this impression, and came to the conclusion that it principally arose from the rhythmic cadence, combined with the hand-clappings, mingled with the vocal sounds and drum-beat. These conclusions led him to collect specimens of frogs from a small vley. Out of these two very minute species gave out loud rapping sounds when confined in a jar; and subsequently, although extremely common in Kaffraria, they were described as new by M. Boulenger in the British Museum (Nat. Hist.) catalogue of Batrachia salientia, 1882. These, as well as the other species collected, belong to African groups widely distributed, especially through the tropics. About the same time (1864) he also arrived at the conclusion that the models of the so-called bee-hive huts of the natives were the termitaria, or white ants' nests, as they are commonly called; that possibly primæval man sheltered himself in deserted termitaria, adapting to them a roof of boughs or leaves, such as the anthropoid apes are known to construct.

Hence it would seem probable that all those primitive races constructing circular-planned dwellings started from the tropics, and that their music and language were to a large extent based on their interpretation of the natural sounds around them, and more particularly on the frog-concert—*Nkuquak* being, as he later found in Efik, the Old Kalabar word for a concert, and *quak*, to clap hands, beat a drum.

The author quotes Burchell, Schweinfurth, Winterbottom, and other observant and careful travellers for descriptions of frog and native music, contrasting and comparing them together. He further shows that, so far as the evidence he has collected goes, neither monkeys, anthropoid apes, nor babies, European or African, clap hands until taught—that it is, in fact, an acquired habit distinct from the stamping of feet. The arms and legs of children when young are thrown upwards and outwards, the hands striving to grip and the feet to push. In North European nations, more especially ourselves, feet and sticks are still often used to accompany music, but hand-clapping only as applause. Similarly castanets, bones, and rattles, except in what are termed nigger minstrelsies, are rare in use, and, before these last were introduced from America, confined principally to ballets. The author notices that they seem to commend themselves to certain classes, which regard operas and theatres with dislike.

In Southern Europe, throughout Africa and the East, as also with all savage tribes, they are common, and form an essential part of the music.

He also traces the ὀλολυγή of the Greeks, the Cybele, Hestia, and Osiris chants, the modern ululuing of Cairo, and the Alleluia Chorus to these animals, quoting Aristotle, Carl Engel, and others.

Next he notices the mode of beating an accompaniment to the Paddlers' song in Africa and America, and its imitation of the frog, this beating of time being also sometimes accompanied by a drum among the Kroomen. In support of this he quotes R. Lauder, Winwood Reade, Harrison, Rankin, Schomburgk, and im-Thurn, showing that the imitation is so perfect that persons are again and again deceived by it, as the author states to have been at times the case with himself in Kaffraria.

He next calls attention to certain vocal sounds of an *ïaö* or *ïaü* kind, their

production by certain frogs and toads, their use in names of rivers, &c., and their reproduction, as well as of certain kwâ and ââp or pââ sounds in human language.

He quotes Livingstone, Darwin, Theocritus, and others, to show that the notes of frogs have called forth admiration from many cultured Europeans.

At the same time he points out that it is the 'relation' in art which produces admiration.

With primitive man utility was the first thought, how to protect and preserve himself. Hence his pleasures and tastes.

The rain following the sun was foretold by the Batrachians, the Kwakwa, which the Greeks and many others believed were sent down from the sky. Hence Ti-kwa, the Kwa unknown deity up-above, the Râ of the Chuana, the Kue-akengteng or Kaang of the Bushmen of the Blue Mountains, the Râ or sun-god of Egypt, the Ra of India, the Ptah and Heka of Egypt, and the Quaqua priests of the Mexican war-god and of Thaloc.

The frog, he believes, was probably or possibly the origin of the *Aius loquens* or *loquax*, the unknown voice, as is *Ka*, the unknowable, in Sanskrit.

He points out that the drums speak articulately throughout Africa, and that the hand-clapping, finger-snappings, and cracking seem also to have or have had meanings like the clicks and the consonants.

In order to verify his conclusions the author went to language, not as a proof of itself, but as a secondary reference. He differs in his conclusions as to the value of grammatical construction, since the common people do not conform to the rules laid down by grammarians. In unwritten tongues he believes that by comparing words with observations of material facts, mental peculiarities, and customs it is far easier to trace their origins than where a language has been long committed to writing. He considers that grammars have been frequently tampered with, as have words, in the interests of rulers and priests. The result of his researches is that, differing as their languages now do, all the Africans are closely connected, and at some distant period were connected also with the Monkey and Naga races of India, as is evidenced by the gigantic statue at Sravana Belyola in Mysore, by certain customs, and by words identical in form and meaning in the language of Africa and India.

He points out that Budas existed in Africa and India, and that probably they did, and perhaps still, exist in Australia and South-Central America.

He agrees with some statements made by Father Torrend in his 'Comparative Grammar of the South African Bantu Languages,' and the statement by this authority that the Tongus use snakes as dogs confirms the conclusion he had previously arrived at—that Jâ or Jâh is the equivalent of Sâ or Sâh.

The value of the prefixes in the so-called Bantu languages as determining race origins he denies, and believes that their use has been misinterpreted.

He believes that an observation of natural facts gives a clue to man's history which is borne out by language, that the mental capacity of wild races inhabiting tropical and semi-tropical climates has been much underrated, and that this is due to a misunderstanding of the relations between man and nature there.

He further believes that he has been able to explain by what causes, apart from natural selection, but upon which it acted, woman first and afterwards man became divested of his hairy coat. His theory, if correct, explains many other subjects which hitherto have evaded research and puzzled inquirers. For instance, the tradition about elf-locks, the use of stone-flakes, and why they are found scattered about the surface of the world, their forms and meanings, besides several unintelligible parables, riddles, and myths.

Lastly, he agrees with those conclusions of Dr. W. Stukeley which he has examined, and believes that, could he have had access to the facts the author possesses, he would have advanced our knowledge of antiquity and true religion instead of having been doomed to ignominy as a crack-brained lunatic.

The author acknowledges his indebtedness to the works of many travellers and vocabularists in verifying his conclusions. Dr. Winterbottom's work on Sierra Leone first led him to believe that he was on the right spoor, while 'Livingstone's Travels' supplied him in Africa with valuable facts and suggestions.

At times he has felt so sceptical as to the value of the work he was doing that he has abandoned it for years. With this feeling strong on him he read Schweinfurth's 'Heart of Africa,' and from this admirable repertory of careful observation he drank in new hope and fresh faith. He cannot express too strongly the value he sets on it, or the admiration it has called forth by its profoundly philosophical reflections and manly, honest tone.

Finally, whatever love of natural history the author has he owes mainly to an early perusal of the 'Voyage of a Naturalist in the *Beagle*.'

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4. *On the Prehensile Power of Infants.* *By* Dr. Louis Robinson.

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5. *The Integumentary Grooves on the Palm of the Hand and Sole of the Foot of Man and the Anthropoid Apes.* *By* David Hepburn, *M.D., C.M., F.R.S.E., Senior Demonstrator of Anatomy, University of Edinburgh.*

After a short introductory statement the author drew attention to recent literature dealing with this subject, and then proceeded to summarise and contrast the functions of the hand in man and apes. This was followed by a comparison of the obvious surface characters and differences found in the hands of man and apes. The grouping of the muscles and their modes of action were next dealt with. It was then shown that it was possible for the flexor, adductor, and opposing muscles to leave their imprint on the palm.

As a result of flexion the skin of the palm and of the digits is thrown into folds separated by grooves, whose direction is always more or less transverse to the long axis of these parts, but the transverse direction may be modified by special conditions, such as the increased development of certain muscles. The movement of adduction or contraction results in the narrowing of the palm, and this is indicated by grooves which run in the long axis of the palm; but since the muscles of this group arise in relation to the middle line of the hand, the grooves radiate more or less distinctly from a point in front of the wrist.

Similarly the movement of opposition is indicated by oblique lines, but these usually blend with the radiating lines.

Following this, the hand of each ape was taken in turn, its principal characters pointed out, the grooves on its palm indicated by reference to casts and drawings, and the variations from the typical arrangement of the grooves accounted for. After the palm of the gibbon, orang-utan, chimpanzee, and gorilla had been treated in this way the hand of man was similarly discussed.

Here it was shown that the same grooves prevail throughout the series, but that the lines of flexion become modified as the muscles in the ball of the thumb and ball of the little finger increase in size and importance. From being transverse in the gibbon, they gradually become more and more oblique, until, as in man, the outer end of the anterior line is pushed towards the cleft between the index and medius digits, while the inner end of the middle line is smoothed down so that it no longer reaches the inner border of the palm. Again, what is a posterior transverse line in the gibbon is lost in man.

Of the radiating or longitudinal lines only one is left in man, and that occupies the middle of the palm; but even this may not be constant. The oblique line which in man surrounds the ball of the thumb is partly due to opposition and partly due to adduction, so that it may also be regarded as one of the radiating series of grooves. Lines to indicate opposition of the little finger are ill-defined even in man, where they may be seen as faint lines running somewhat parallel to the oblique line of the thumb, *i.e.*, outwards and forwards from the inner border of the palm.

Following the hand, the foot was treated in a similar way. First, a summary and contrast of its functions in man and apes, then a statement of the surface characters and differences in the feet of man and the apes. In the foot there are

no muscles of opposition, so that only two groups of muscles, viz.—flexors and adductors—are concerned in producing the plantar grooves, which are therefore restricted to transverse and longitudinal or radiating grooves, with such modifications of these as special circumstances may produce. Then there followed a detailed description of the naked-eye characters and the plantar grooves of the feet of the gibbon, orang, chimpanzee, gorilla, and man. The last was discussed, first, in reference to the foot of the newborn infant; second, in reference to the foot of the Australian aboriginal; and third, in reference to the foot of civilised man.

In all the apes and in the foot of the newborn infant it was shown that the same arrangement of transverse and longitudinal lines prevailed, subject to such modifying causes as the length of metatarsal bones, the amount of web between individual digits, the size of the hallux, and the angle at which it springs from the inner border of the foot. In the apes the flexion lines of the hallux and sole of the foot are distinct from each other, and it is only in the case of man, after his great toe has become parallel to the other digits, that these lines become to a certain extent blended. Of adduction lines, *i.e.*, longitudinal or radiating, the newborn human infant shows distinctly the one which indicates adduction of the hallux.

After the foot has become chiefly an organ of support and locomotion the character of the grooves undergoes considerable change. This may be seen clearly in the foot of the Australian aboriginal, where the primitive and original grooves are smoothed out, while a new set makes its appearance. These are lines to express flexion, and are represented by two or three transverse lines between the ball of the heel and ball of the great toe. Adduction is also indicated by an indefinite mesial line of small dimensions. In the foot of civilised man the use of boots has greatly restricted the freedom of movement, and consequently the lines are still more indefinite, although they conform to the plan laid down.

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6. *On the Contemporaneity of Man and the Moa.* *By* H. O. Forbes.

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7. *A Discussion on Human Osteometry was opened by* Dr. J. G. Garson.

Sir Wm. Turner explained a method, which he had devised, of taking the capacity of crania by the use of shot poured into the cavity of the skull through a funnel, the spout of which was two centimetres long and two centimetres wide. The details of the method are given in his 'Memoir on Human Crania in the Reports of H.M.S. *Challenger*,' Part XXIX. It was claimed for the method that it gave the actual capacity, and did not overmeasure it, as is the case with Broca's method. A demonstration of the method was given on a skull, the exact cubic capacity of which had been previously determined by means of water.

TUESDAY, AUGUST 9.

The following Papers were read:—

1. *Exhibition of Composite Photographs of United States Soldiers.* *By* Dr. J. G. Garson.

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2. *Observations as to Physical Deviations from the Normal as seen among* 50,000 *Children.* *By* Francis Warner, *M.D.*

Taking all cases of deviation from normal development, the percentage on the 50,000 children is for boys 13·4, for girls 9·6. It is noteworthy that the distribution

of these cases in certain districts appeared to vary much; their relative percentage frequency is for English children 10·8, Irish 19·9, Jew 7·5; among the upper social class 11·5, falling to 10·2 among poorer children. Among these 'development cases' the power of resistance is low, many becoming thin, with disordered nerve-system. Of the 50,000 children 7·3 per cent. were reported by teachers as dull, and of the 5,851 'development cases' 40 per cent. were dull at lessons. The most important defects were found to be those of the cranium as indicated by the proportion among them delicate, dull, and with nerve-disorder or weakness; many of these cases are doubtless due to rickets. Small heads were specially common among girls, the only defect to which they seem specially liable. The palate comes next in frequency and importance. The import of defects of external ear and other parts is shown. It is seen that all forms of defectiveness in development of visible parts of the body have a significance; they are commoner among boys than girls, but deviations from the normal development are accompanied by more weakness of constitutional power among girls.

An account is given of different groups of children, the numbers of each class among the 50,000 (boys, 26,894; girls, 23,143) being given. Group I. Normal children, in whom no defect was found; boys 21,315; girls, 19,536, or of boys 70 per cent., of girls 84 per cent. Group II. contains the remainder of the children in whom some deviation from the normal was seen or mental dulness was reported by the teachers. Boys, 5,579; girls, 3,607; total, 9,186; boys, 20·7 per cent.; girls, 15·5 per cent.; total, 18·3 per cent. Notes were taken of each of these cases; they are analysed in succeeding groups, many children having more than one defective condition appearing in two or more groups. Group III. Children reported as dull at school work, but presenting no visible defects. Boys, 185; girls, 134; total, 319. These cases appeared sound in body and brain; perhaps they would gain more from technical education. Group IV. Children feeble-minded or exceptional in mental status. Boys, 124; girls, 110. These were all very difficult cases to deal with. These children were scattered through most schools, and need special care. Group V. Epileptics, and children with history of fits during school life. Boys, 36; girls, 18. Group VI. Crippled, paralysed, maimed, and deformed. Boys, 155; girls, 84. These children differ so greatly that the needs of each must be separately considered. Group VII. Children deaf or partially deaf. Boys, 34; girls, 33. There were also 51 children seen in a school for the dumb. Group VIII. Eye cases. Boys, 836; girls, 637. Only obvious defects were noted; tests for sight were not employed, and ophthalmia, though seen in day-schools, was not recorded. Group IX. Children pale, thin, or delicate, 1,030 boys, 973 girls. Of these cases 1,459 presented some defects in development; this was also noticeable among well-fed children. Group X. Children of defective development described above. Group XI. Cases with slight defect or disorder of the nerve system. Boys, 3,413; girls, 2,074. In certain sections of this group the signs seen indicated low-class make, in other classes such as is commonly called 'nervousness or nerve-weakness.' Group XIV. Children reported by the teachers as dull in school. Boys, 2,216; girls, 1,463; total, 3,679. Group XV. Children requiring special educational care, including those mentally defective, epileptics, crippled, and those of defective constitution. Boys, 473; girls, 344, or a percentage of 1·6 on the 50,000 children. Groups XIII., XVI., XVII., XVIII. contain children with various combined conditions of defectiveness. It is mainly by description of children according to their combined defects that we may best classify them for consideration of their special needs. A table giving detailed conditions is appended to the paper.

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3. *On the Brain of an Australian.* *By* Professor A. Macalister.

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4. *On Skulls from Mobanga, Upper Congo.* *By* Professor A. Macalister.

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5. *On some Facial Characters of the Ancient Egyptians.* *By* Professor A. Macalister.

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6. *On some very Ancient Skeletons from Medum, Egypt.* *By* J. G. Garson, *M.D.*

The series consists of twelve skeletons and several skulls obtained by Mr. Flinders Petrie from Medum, in Egypt, and have been determined by him to belong to the fourth dynasty, which dates from 3800 to 4000 B.C. If this is correct these bones are the remains of persons who lived, in round numbers, about 6,000 years ago.

Stature.—Estimated from the length of the femur and tibia, according to the European standard, the average stature of the people they represent would have been about 1·64 metre, or 5 feet 4½ inches.

The average lengths of the tibia and radius are the same as in Europeans, according to Rollett's averages, but those of the femur and humerus are shorter. The proportion which the tibia bears to the femur is as 83·5 to 100, that in Europeans is 80·4, and in the negro it is 82·9. The radio-humeral index in the Medum specimens is 78·8, in Europeans 72·5, and in negroes 79. It is very apparent, therefore, that the proportions of both the upper and lower limbs of the Medum skeletons agree closely with those of negroes, and differ essentially from those of Europeans.

The pelvic measurements give a brim index of 85·7, while in the European it is 80, and in the negro 89. In this respect the negro affinity is not so marked as in the limbs, but still the pelvic characters are more negro than European.

The characters of the skull agree generally with those of Egyptians of later date. The muscular ridges are moderately well developed, the sutures are simple in character and either open or nearly obliterated. The cephalic index averages 75·8. This is almost the same as that of ancient Egyptians measured by Broca, which averaged 75·3. Ten of the Medum specimens are dolichocephalic, eleven are mesaticephalic, and two are brachycephalic (the limits of these groups being respectively 70 to 74·9, 75 to 79·9, and 80 to 84·9). The cephalic index of Nubians and negroes ranges from 73 to 75; that of Europeans is 78.

The nasal index of the Medum skulls averages 47·9, while that of Nubians is 55·1, and that of Europeans is 46. Ten of the Medum specimens are leptorhine, seven are mesorhine, and two are platyrhine.

The orbital index of the Medum skulls averages 86·8, the gnathic index is 95·5, the upper face index (Kollmann) is 56·4, and the total face index (Kollmann) 84·8, the stephanic index is 90·8, and the bigonial is 75.

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7. *On a Skull from Port Talbot, Glamorganshire.* *By* C. Phillips, *B.A.*

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8. *On Trepanning the Human Skull in Prehistoric Times.* *By* Robert Munro, *M.A.*, *M.D.*

A few years ago the Most Hon. the Marquis of Bute, K.T., presented to the National Museum of Scotland some portions of the osseous remains of a human body which were taken out of a grave near Mountstuart House, on the island of Bute. Along with these bones were also found an urn, a jet necklace, and a small bit of thin bronze of an indeterminate character, all of which justified the opinion that the interment took place in the early Bronze Age.

According to Dr. Beddoe, to whom these bones were submitted for examination, their owner was a young woman whose wisdom teeth had not yet appeared.

But the special point to which Dr. Munro directed attention was a cup-shaped hollow, situated on the left side of the frontal bone, and having in its centre a small perforation. This hollow lay immediately above the temporal fossa, and its

anterior margin, which just overlapped the temporal ridge, was exactly one inch from the outer angle of the orbit. The exterior edge of the concavity, which measured about an inch in diameter, was slightly raised above the normal surface of the surrounding bone, and presented an appearance somewhat like an everted lip. This lip was a particularly noteworthy feature, as it was the result of a pathological process, which could only take place in the living body. The actual perforation, which did not exceed a quarter of an inch in its greatest diameter, took the form of a bluntly defined triangle bounded by thin edges.

From a careful study of these facts, no experienced surgeon, Dr. Munro maintained, could come to any other conclusion than that this perforation had been intentionally performed on the living subject, and that the subject survived the operation for a considerable time, possibly many years. In other words, they had here the unwritten records of a successful case of trepanning in the early Bronze Age; but for what purpose the operation was performed there was no evidence to show.

But, however correct this induction might be, it was only a single example on which it was founded, and, consequently, the evidence was inadequate to prove the wider generalisation which it was the author's object in his communication to establish, viz., that trepanning the human skull for therapeutic purposes was not an uncommon surgical operation among the Neolithic inhabitants of Europe. Such a generalisation must be based on a number of examples widely distributed both in space and time, and to these the author then briefly referred. Commencing with the year 1873, when Dr. Prunières first directed attention to a worked piece of a human skull from a dolmen at Lozère, he traced the gradual development of opinion on this subject as influenced by the various subsequent discoveries till 1876, when Dr. Paul Broca delivered his memorable address at the International Congress of Prehistoric Archæology at Buda-Pesth, and finally demonstrated that the prehistoric people of France practised two forms of trepanning—one during life (*trépanation chirurgicale*) and the other after death (*trépanation posthume*). Since Broca's time further evidence in support of this opinion has come to light, and the story in the hands of Dr. Munro is carried down to the present time. The various hypotheses as to the object for which the operation was performed were then discussed, and it was finally shown that in some cases at least the motive was a pure surgical purpose. The author concluded his paper as follows:—

'On a previous occasion, when treating of the lake dwellings of Europe, I drew special attention to the advanced state of the culture and civilisation which their remains indicated. A similar reflection is now suggested by the facts which I have just brought under your notice. It is impossible to suppose that the widely scattered races inhabiting primeval Europe—a country then so inaccessible owing to its impenetrable forests and marshes, impassable mountains, and great rivers—could have developed at so many independent centres a custom indicative of such a high order of speculative intelligence. It is therefore to the original home of the Neolithic civilisation, wherever that may be, that we must look for the origin of the custom of trepanning the human skull, and even there its antiquity would be probably lost in the long vista of preceding ages.'[1]

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9. *On the Use of Narcotics by the Nicobar Islanders, and certain Deformations connected therewith.* *By* E. H. Man.

Mr. E. H. Man gave an account of the use of narcotics by the Nicobarese, notably in connection with the habit common among so many of the races of Transgangetic India and the Archipelago of taking frequent quids of betel-nut and quicklime throughout the day; so firm a hold has this practice on both sexes that 'betel-quid-taking-time' is a recognised expression, signifying an interval of some fifteen minutes' duration. Betel-chewing is commenced at the early age of ten or twelve, but instances are by no means rare of children who have acquired

[1] This paper, *in extenso*, will be published in the *Proceedings of the Society of Antiquaries of Scotland*, vol. xxvi. 1891–92.

the habit before attaining six and even four years of age; it is but fair to add that this infantile precocity is not encouraged by the parents. Among the supposed benefits resulting from the custom are preservation of the teeth and mitigation of the attacks of malarial fever, which is so prevalent in these islands. Strange as it may appear, the sense of taste does not seem to be vitiated in the slightest degree, nor is the appetite impaired.

The intentional *staining* and unintentional dental deformation which this habit produces in a few weeks, under certain conditions, are explained, and the misstatements due to misapprehension of the real facts of the case which are found in earlier accounts of these islanders are severally noted. Mr. Man concluded his paper with a few remarks on the cranial and facial deformations, which are considered by the natives of the central and southern communities to be of the highest importance, and to the production of which the Nicobarese mother devotes much care and attention during the first two years or so of a child's life. The method pursued is described carefully, and it is satisfactory to note that it cannot cause the little one even momentary discomfort.

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10. *Report of the Indian Committee.*—See Reports, p. 615.

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11. *Report of the Prehistoric Remains of Glamorganshire Committee.* See Reports, p. 544.

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12. *Report of the Elbolton Cave Committee.*—See Reports, p. 266.

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13. *Exhibition of the Philograph—a simple Apparatus for the Preparation of Lecture Diagrams. By* G. W. Bloxam, *M.A.*

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14. *Exhibition of Photographs representing the Prehensile Power of Infants. By* L. Robinson, *M.D.*

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[*An asterisk* (*) *signifies that no abstract of the communication is given.*]

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Together with the Transactions of the Sections, Professor W. H. Flower's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTIETH MEETING, at Leeds, August 1890, *Published at* £1 4*s*.

CONTENTS:—Report of the Corresponding Societies Committee;—Third Report of the Committee to arrange an Investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom, in co-operation with the Local Societies represented on the Association;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Fifth Report on Electrolysis in its Physical and Chemical Bearings;—Sixth Report on the best methods of recording the direct Intensity of Solar Radiation;—Report of the Committee for co-operating with Dr. Kerr in his Researches on Electro-optics;—Report on Molecular Phenomena associated with the Magnetisation of Iron;—Tenth Report on the Earthquake and Volcanic Phenomena of Japan;—Sixth Report on the best means of comparing and reducing Magnetic Observations;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Sixth Report of the Committee for promoting Tidal Observations in Canada;—Report on the present state of our Knowledge in Electrolysis and Electro-chemistry;—Report on the Preparation of a new series of Wave-length Tables of the Spectra of the Elements and Compounds;—Report on the Bibliography of Spectroscopy;—Fourth Report on the Influence of Silicon on the Properties of Iron and Steel;—Second Report on the best method of establishing an International Standard for the Analysis of Iron and Steel:—Report on the Action of Light on the Hydracids of the Halogens in presence of Oxygen;—Third Report on the present Methods of Teaching Chemistry;—Fourth Report on the Properties of Solutions;—Fourth Report on the Bibliography of Solution;—Discussion on the Theory of Solution;—Provisional Report on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Report on the Absorption Spectra of Pure Compounds;—Report on the best methods for the Registration of all Type Specimens of Fossils in the British Isles;—Eighteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Sixteenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Final Report on an Ancient Sea-beach near Bridlington Quay;—Report on the Cretaceous Polyzoa;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Fourth and final Report on the 'Manure' Gravels of Wexford;—Eighth Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Report on the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth;—Third Report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Committee for making a Digest of the Observations on the Migration of Birds;—Third Report on the Disappearance of Native Plants from their Local Habitats;—Fourth Report of the Committee for taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon;—Report of the Committee for improving and experimenting with a Deep-sea Tow-net for opening and closing under water;—The probable Effects on Wages of a general Reduction in the Hours of Labour;—Fourth Report on the best methods of ascertaining and measuring Variations in the Value of the Monetary Standard;—Report on the teaching of Science in Elementary Schools;—Fourth Report as to the Statistical Data available for determining the amount of the Precious Metals in use as Money in the principal Countries, the chief Forms in which the Money is employed, and the Amount annually used in the Arts;—On some new Telemeters or Range-finders;—Second Report on the Investigation of the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models;—Report on the Geography and the Habits, Customs, and Physical Characters of the Nomad Tribes of Asia Minor and Northern Persia, and on the excavation of Sites of Ancient Occupation;—Report on the Habits, Customs, Physical Characters, and Religions of the Natives of India;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries';—Fourth Report on the Prehistoric Inhabitants of the British Islands;—Report on

the Calculation of the Anthropological Measurements taken at Newcastle;—Sixth Report on the North-Western Tribes of the Dominion of Canada.

Together with the Transactions of the Sections, Sir F. A. Abel's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTY-FIRST MEETING, at Cardiff, August 1891, *Published at* £1 4*s*.

CONTENTS:—Report of the Corresponding Societies Committee;—Report on the present state of our knowledge of Thermodynamics, specially with regard to the Second Law;—Sixth Report on Electrolysis in its Physical and Chemical Bearings;—Eleventh Report on the Earthquake and Volcanic Phenomena of Japan;—Second Report of the Committee for calculating Tables of certain Mathematical Functions, and, if necessary, taking steps to carry out the Calculations, and publishing the results in an accessible form;—Fifth Report on the application of Photography to the Elucidation of Meteorological Phenomena;—Report on the Discharge of Electricity from Points;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Third (interim) Report on the various Phenomena connected with the Recalescent Points in Iron and other Metals;—Second (interim) Report of the Committee for co-operating with Dr. Kerr in his Researches on Electro-optics;—Report of the Committee for co-operating with Dr. C. Piazzi Smyth in his Researches on the Ultra-violet Rays of the Solar Spectrum;—Report on the best means of Comparing and Reducing Magnetic Observations;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Interim Report of the Committee for carrying on the Tables connected with the Pellian Equation from the Point where the work was left by Degen in 1817;—Seventh Report on the best methods of recording the direct Intensity of Solar Radiation;—Report on the Preparation of a new series of Wave-length Tables of the Spectra of the Elements and Compounds;—Interim Report on the Action of Light upon Dyed Colours;—Report (provisional) on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Third Report on the Bibliography of Spectroscopy;—Fifth Report on Isomeric Naphthalene Derivatives;—Fifth Report on the Bibliography of Solution;—Third Report on the best method of establishing an International Standard for the Analysis of Iron and Steel;—Provisional Report on the direct formation of Haloid Compounds from pure materials;—Report (provisional) on the Absorption Spectra of Pure Compounds;—Nineteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Second Report on the Registration of all the Type Specimens of British Fossils;—Seventeenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Second Report on the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom;—Report on the advisability and possibility of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions;—Report of the Committee for working the very Fossiliferous Transition Bed between the Middle and Upper Lias in Northamptonshire, in order to obtain a more clear idea of its fauna, and to fix the position of certain species of Fossil Fish, and more fully investigate the horizon on which they occur;—Report of the Committee to complete the investigation of the Cave at Elbolton, near Skipton, in order to ascertain whether Remains of Palæolithic Man occur in the Lower Cave Earth;—Report of the Committee for carrying on excavations at Oldbury Hill, near Ightham, in order to ascertain the existence or otherwise of Rock-shelters at this spot;—Fourth Report on the present state of our knowledge of the Zoology and Botany of the West India Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Draft Report on the present state of our knowledge of the Zoology of the Sandwich Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna;—Fifth Report of the Committee for taking steps for the establishment of a Botanical Laboratory at Peradeniya, Ceylon;—Fourth Report on the Disappearance of Native Plants from their Local Habitats;—Report of the Committee for making a digest of the observations on the Migration of Birds at Lighthouses and Light-vessels, which have been carried

on by the Migration Committee of the British Association;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Committee for improving and experimenting with a Deep-sea Tow-net for opening and closing under water;—Report on the teaching of Science in Elementary Schools;—Third Report on the investigation of the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries';—Seventh Report on the North-western Tribes of the Dominion of Canada;—Fifth Report on the Prehistoric Inhabitants of the British Islands;—Fourth and Final Report of the Committee to arrange an Investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom in co-operation with the local societies represented on the Association;—On the Capture of Comets by Planets, especially their Capture by Jupiter;—The Recent Progress of Agriculture in India.

Together with the Transactions of the Sections, Dr. Huggins's Address, and Resolutions of the General Committee of the Association.

The following Publications are also on sale at the Office of the Association:—

Index to the Reports, 1831–1860, 12*s*.

Lalande's Catalogue of Stars, £1 1*s*.

Rules of Zoological Nomenclature, 1*s*.

On the Regulation of Wages by means of Lists in the Cotton Industry:—Spinning, 2*s*.; Weaving, 1*s*.

Second Report on the present Methods of Teaching Chemistry, 6*d*.

Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements, 6*d*.

Second Report on the Development of Graphic Methods in Mechanical Science, 1*s*.

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NATURAL HISTORY

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE.

LIST

OF

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CORRECTED TO JANUARY 1893.

Office of the Association:
BURLINGTON HOUSE, LONDON, W.

OFFICERS AND COUNCIL, 1892–93.

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LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1892.

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* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant General Secretary.

Year of Election.

1887. *Abbe, Professor Cleveland. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1881. *Abbott, R. T. G. Whitley House, Malton.
1887. ‡Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, K.C.B., D.C.L., D.Sc., F.R.S., V.P.C.S., President of the Government Committee on Explosives. The Imperial Institute, Imperial Institute-road, London, S.W.
1886. ‡ABERCROMBY, The Hon. RALPH, F.R.Met.Soc 21 Chapel-street, Belgrave-square, London, S.W.
1891. §ABERDARE, The Right Hon. Lord, G.C.B., F.R.S., F.R.G.S. Duffryn, Mountain Ash, South Wales.
1885. *ABERDEEN, The Right Hon. the Earl of, LL.D. 37 Grosvenor-square, London, W.
1885. ‡Aberdeen, The Countess of. 37 Grosvenor-square, London, W.
1885. ‡Abernethy, David W. Ferryhill Cottage, Aberdeen.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.

Year of Election.

1873. *Abney, Captain W. de W., R.E., C.B., D.C.L., F.R.S., F.R.A.S., F.C.S. Willeslie House, Wetherby-road, South Kensington, London, S.W.
1886. ‡Abraham, Harry. 147 High-street, Southampton.
1877. ‡Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.
1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, London, S.W.
1869. ‡Acland, Charles T. D., M.P. Sprydoncote, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. 22 Cheyne-gardens, Chelsea, London, S.W.
1873. *Acland, Rev. H. D., M.A. Luccombe Rectory, Taunton.
1873. *Acland, Sir Henry W. D., Bart., K.C.B., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 74 Brook-street, London, W.
1860. ‡Acland, Sir Thomas Dyke, Bart., M.A., D.C.L. Sprydoncote, Exeter; and Athenæum Club, London, S.W.
1887. ‡Adami, J. G., B.A. New Museums, Cambridge.
1892. §Adams, David. Rockville, North Queensferry.
1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1876. ‡*Adams, James.* 9 *Royal-crescent West, Glasgow.*
1871. §Adams, John R. 2 Nutley-terrace, Hampstead, London, N.W.
1879. *Adams, Rev. Thomas, M.A., D.C.L., Principal of Bishop's College, Lennoxville, Canada.
1877. ‡Adams, William. 3 Sussex-terrace, Plymouth.
1869. *Adams, William Grylls, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.
1879. ‡Adamson, Robert, M.A., LL.D., Professor of Logic and Political Economy in Owens College, Manchester. 1 Derby-road, Fallowfield, Manchester.
1890. ‡Addyman, James Wilson, B.A. Belmont, Starbeck, Harrogate.
1890. ‡Adeney, W. E., F.C.S. Royal University of Ireland, Earlsford-terrace, Dublin.
1865. *Adkins, Henry. Northfield, near Birmingham.
1883. ‡Adshead, Samuel. School of Science, Macclesfield.
1884. ‡Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.
1887. ‡Agnew, William. Summer Hill, Pendleton, Manchester.
1884. ‡Aikins, Dr. W. T. Jarvis-street, Toronto, Canada.
1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §Aitken, John, F.R.S., F.R.S.E. Darroch, Falkirk, N.B.
Akroyd, Edward. Bankfield, Halifax.
1884. *Alabaster, H. 22 Paternoster-row, London, E.C.
1886. *Albright, G. S. The Elms, Edgbaston, Birmingham.
1862. ‡Alcock, Sir Rutherford, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.
1861. **Alcock, Thomas, M.D. Oakfield, Sale, Manchester.*
*Aldam, William. Frickley Hall, near Doncaster.
1887. ‡*Alexander, B. Fernlea, Fallowfield, Manchester.*
1891. ‡Alexander, D. T. Dynas Powis, Cardiff.
1883. ‡Alexander, George. Kildare-street Club, Dublin.

Year of Election.

1888. *Alexander, Patrick Y. Experimental Works, Bath.
1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.
1858. ‡Alexander, William, M.D. Halifax.
1891. *Alford, Charles J., F.G.S. Coolivin, Hawkwood-road, Boscombe, Hants.
1883. ‡Alger, Miss Ethel. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1867. ‡Alison, George L. C. Dundee.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, London, E.C.
1871. ‡Allen, Alfred H., F.C.S. 67 Surrey-street, Sheffield.
1887. *Allen, Arthur Ackland. Overbrook, Kersal, Manchester.
1879. *Allen, Rev. A. J. C. Cava House, Barton-road, Cambridge.
1887. *Allen, Charles Peter. Overbrook, Kersal, Manchester.
1888. ‡Allen, F. J. Mason College, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1887. §Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
1861. ‡Allen, Richard. Didsbury, near Manchester.
1887. *Allen, Russell. 2 Parkwood, Victoria Park, Manchester.
1891. ‡Allen, W. H. 24 Glenroy-street, Roath, Cardiff.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
1889. §Allhusen, Frank. Low Fell, Gateshead.
*Allman, George J., M.D., LL.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1887. *Allnutt, J. W. F., M.A. 12 Chapel-row, Portsea, Hants.
1886. ‡Allport, Samuel. 50 Whittall-street, Birmingham.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1891. ‡Ambrose, D. R. 4 Richmond-terrace, Cardiff.
1883. §Amery, John Sparke. Druid House, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid House, Ashburton, Devon.
1884. ‡Ami, Henry. Geological Survey, Ottawa, Canada.
1885. ‡Anderson, Charles Clinton. 4 Knaresborough-place, Cromwell-road, London, S.W.
1850. ‡Anderson, Charles William. Belvedere, Harrogate.
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *Anderson, Hugh Kerr. Frognal Park, Hampstead, London, N.W.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1892. §Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1888. *Anderson, R. Bruce. 35A Great George-street, London, S.W.
1887. ‡Anderson, Professor R. J., M.D. Queen's College, Galway.
1889. ‡Anderson, Robert Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1880. *Anderson, Tempest, M.D., B.Sc. 17 Stonegate, York.
1886. *Anderson, William, D.C.L., F.R.S., M.Inst.C.E. Lesney House, Erith, Kent.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1891. ‡Andrews, Thomas. 163 Newport-road, Cardiff.

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1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Gosford Lodge, Coventry.
1883. ‡Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §Angell, John, F.C.S. 5 Beacons-field, Derby-road, Fallowfield, Manchester.
1886. §Annan, John, J.P. Whitmore Reans, Wolverhampton.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.
1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1886. ‡*Arblaster, Edmund, M.A. The Grammar School, Carlisle.*
1870. ‡Archer, Francis. 14 Cook-street, Liverpool.
1874. ‡Archer, William, F.R.S., M.R.I.A. 11 South Frederick-street, Dublin.
1884. **Archibald, E. Douglas. Grosvenor House, Tunbridge Wells.*
1851. ‡Argyll, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyllshire.
1884. §Arlidge, John Thomas, M.D., B.A. The High Grove, Stoke-upon-Trent.
1883. §Armistead, Richard. 28 Chambres-road, Southport.
1883. *Armistead, William. 15 Rupert-street, Compton-road, Wolverhampton.
1887. ‡Armitage, Benjamin. Chomlea, Pendleton, Manchester.
1861. ‡Armitage, William. 95 Portland-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1857. *Armstrong, The Right Hon. Lord, C.B., LL.D., D.C.L., F.R.S. Jesmond Dene, Newcastle-upon-Tyne.
1879. *Armstrong, Sir Alexander, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Albany, London, W.
1886. ‡Armstrong, George Frederick, M.A., F.R.S.E., F.G.S., Regius Professor of Engineering in the University of Edinburgh. The University, Edinburgh.
1873. ‡Armstrong, Henry E., Ph.D., F.R.S., Sec.C.S., Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W. 55 Granville Park, Lewisham, S.E.
1876. ‡Armstrong, James. Bay Ridge, Long Island, New York, U.S.A.
1889. †Armstrong, John A. 32 Eldon-street, Newcastle-upon-Tyne.
1884. ‡Armstrong, Robert B. Junior Carlton Club, Pall Mall, London, S.W.
Armstrong, Thomas. Higher Broughton, Manchester.
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1886. ‡Ascough, Jesse. Patent Borax Company, Newmarket-street, Birmingham.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889. §Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.
1873. ‡*Ashton, John. Gorse Bank House, Windsor-road, Oldham.*
Ashton, Thomas, J.P. Ford Bank, Didsbury, Manchester.
1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
1866. ‡Ashwell, Henry. Woodthorpe, Nottingham.

Year of Election.

*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
1887. ‡Ashworth, Mrs. Harriet. Thorne Bank, Heaton Moor, near Stockport.
Ashworth, Henry. Turton, near Bolton.
1888. *Ashworth, J. J. 39 Spring-gardens, Manchester.
1890. ‡Ashworth, J. Reginald. 20 King-street, Rochdale.
1887. ‡Ashworth, John Wallwork. Thorne Bank, Heaton Moor, near Stockport.
1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. 93 Fellows-road, London, N.W.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1887. §Atkinson, Rev. C. Chetwynd, M.A. Fairfield House, Ashton-on-Mersey.
1865. *Atkinson, Edmund, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1884. ‡Atkinson, Edward, Ph.D., LL.D. Brookline, Massachusetts, Boston, U.S.A.
1863. **Atkinson, G. Clayton.* 21 *Windsor-terrace, Newcastle-on-Tyne.*
1861. ‡*Atkinson, Rev. J. A. Longsight Rectory, near Manchester.*
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡Atkinson, Robert William, F.C.S. 44 Loudoun-square, Cardiff.
1863. *Attfield, Professor J., M.A., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1886. ‡Aulton, A. D., M.D. Walsall.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Gables, Winchester.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1881. ‡Axon, W. E. A. Fern Bank, Higher Broughton, Manchester.
1888. ‡Ayre, Rev. J. W., M.A. 30 Green-street, Grosvenor-square, London, W.
1877. *Ayrton, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W.

*Babington, Charles Cardale, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
1884. ‡Baby, The Hon. G. Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, London, N.W.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1881. ‡Baden-Powell, Sir George S., K.C.M.G., M.A., M.P., F.R.A.S., F.S.S. 8 St. George's-place, Hyde Park, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡*Bagrual, P. H. St. Stephen's Club, Westminster, S.W.*
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1892. §Baildon, H. Bellyer. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1878. ‡*Bailey, John. The Laurels, Wittington, near Hereford.*

Year of Election.

1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡Bailey, W. H. Summerfield, Eccles Old-road, Manchester.
1866. ‡Baillon, Andrew. British Consulate, Brest.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1885. ‡Bain, Alexander, M.A., LL.D., Rector of the University of Aberdeen. Ferryhill Lodge, Aberdeen.
1873. ‡Bain, Sir James, M.P. 3 Park-terrace, Glasgow.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *Baker, Sir Benjamin, K.C.M.G., LL.D., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1866. ‡*Baker, Francis B. Sherwood-street, Nottingham.*
1886. ‡*Baker, Harry. 262 Plymouth-grove, Manchester.*
1891. §Baker, J. W. 195 Castle-road, Roath, Cardiff.
1861. *Baker, John. The Gables, Buxton.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. ‡Baker, W. Proctor. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡Balfour, Isaac Bayley, D.Sc., M.D., F.R.S.L. & E., F.L.S., Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D. 24 Merrion-square, Dublin.
1866. *Ball, Sir Robert Stawell, LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1878. ‡Ball, Valentine, C.B., M.A., LL.D., F.R.S., F.G.S., Director of the Museum of Science and Art, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. §Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. §Bamford, Harry, B.Sc. The Owens College, Manchester.
1882. ‡Bance, Major Edward. Limewood, The Avenue, Southampton.
1870. ‡Banister, Rev. William, B.A. St. James's Mount, Liverpool.
1884. ‡Bannatyne, Hon. A. G. Winnipeg, Canada.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1887. *Barclay, Robert. Springfield, Kersal, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.

Year of Election.

1863. *Barford, James Gale. Wellington College, Wokingham, Berkshire.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. §Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, London, S.E.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Boroughbridge Vicarage, Bridgwater.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡Barkly, Sir Henry, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Binagardens, South Kensington, London, S.W.
1889. ‡Barkus, Dr. B. 3 Jesmond-terrace, Newcastle-upon-Tyne.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1889. ‡Barlow, H. W. L. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. †Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1885. ‡Barlow, William, F.G.S. Hillfield, Muswell Hill, London, N.
1873. †Barlow, William Henry, F.R.S., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. Harlow, Essex.
1889. ‡Barnes, J. W. Bank, Durham.
1868. ‡Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1886. ‡*Barnsley, Charles H.* 32 *Duchess-road, Edgbaston, Birmingham.*
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. §Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1860. ‡Barrett, T. B. 20 Victoria-terrace, Welshpool, Montgomery.
1872. *Barrett, W. F., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Winton Lodge, Crosby, near Liverpool.
1887. ‡Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1881. §Barron, G. B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries. Borrowash, Derby.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.

Year of Election.

1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1858. ‡Barry, Right Rev. Alfred, D.D., D.C.L. Knapdale, Upper Tooting, Surrey.
1862. *Barry, Charles. 15 Pembridge-square, London, W.
1883. ‡Barry, Charles E. 15 Pembridge-square, London, W.
1875. ‡Barry, John Wolfe, M.Inst.C.E. 23 Delahay-street, Westminster, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1892. §Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, George C. T., M.P. St. Margaret's House, Victoria-street, London, S.W.
1892. §Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1892. §Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1882. *Basing, The Right Hon. Lord, F.R.S. 74 St. George's-square, London, S.W.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *Basset, A. B., M.A., F.R.S. Chapel Place Mansions, 322 Oxford-street, London, W.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, London, N.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. 74 Kenilworth-square, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡Bastian, H. Charlton, M.A., M.D., F.R.S., F.L.S., Professor of the Principles and Practice of Medicine in University College, London. 8A Manchester-square, London, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡Bateman, A. E., C.M.G. Board of Trade, London, S.W.
1873. *Bateman, Daniel. Wissahickon, Philadelphia, U.S.A.
1868. ‡Bateman, Sir Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.R.G.S., F.L.S. Home House, Worthing.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡Bateson, William, B.A. St. John's College, Cambridge.
1851. ‡Bath and Wells, The Right Rev. Lord Arthur Hervey, Lord Bishop of, D.D. The Palace, Wells, Somerset.
1881. *Bather, Francis Arthur, M.A., F.G.S. 207 Harrow-road, London, W.
1836. ‡Batten, Edmund Chisholm. Thorn Falcon, near Taunton, Somerset.
1863. §Bauerman, H., F.G.S. 9 Hazlebourne-gardens, Cavendish-road, Balham, London, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. §Bayly, F. W. Royal Mint, London, E.
Bayly, John. Seven Trees, Plymouth.

Year of Election.

1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 3 Church-walk, Oxford.
1887. ‡*Baynton, Alfred.* 28 *Gilda Brook Park, Eccles, Manchester.*
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Hatherop Castle, Fairford, Gloucestershire.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *Beale, Lionel S., M.B., F.R.S., Professor of the Principles and Practice of Medicine in King's College, London. 61 Grosvenor-street, London, W.
1882. §Beamish, Lieut.-Colonel A. W., R.E. 18 De Vere-gardens, London, W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡Beard, Mrs. 13 South-hill-road, Toxteth Park, Liverpool.
1889. §Beare, Professor T. Hudson, F.R.S.E. University College, London, W.C.
1887. ‡Beaton, John, M.A. 219 Upper Brook-street, Chorlton-on-Medlock, Manchester.
1842. *Beatson, William. Ash Mount, Rotherham.
1888. ‡*Beatson, W. B., M.D.* 11 *Cavendish-place, Bath.*
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, London, W.
1886. ‡Beaugrand, M. H. Montreal.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. Emmanuel College, Cambridge.
1885. §Beaumont, W. W., M.Inst.C.E., F.G.S. Melford, Palace-road, Tulse Hill, London, S.W.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, London, S.W.
1887. *Beckett, John Hampden. Corbar Hill House, Buxton, Derbyshire.
1885. §Beddard, Frank E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London. Society's Gardens, Regent's Park, London, N.W.
1870. §Beddoe, John, M.D., F.R.S. The Chantry, Bradford-on-Avon.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. ‡Bedford, James E., F.G.S. Clifton-villas, Cardigan-road, Leeds.
1891. §Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡Bedson, P. Phillips, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1891. *Belinfante, L. L., B.Sc., Assist.-Sec. G.S. Geological Society, Burlington House, London, W.
1892. §Bell, A. Beatson. 143 Princes-street, Edinburgh.
1873. ‡Bell, Asahel P. 32 St. Anne's-street, Manchester.
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1880. §Bell, Henry Oswin. 13 Northumberland-terrace, Tynemouth.

Year of Election.

1862. *Bell, Sir Isaac Lowthian, Bart., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡Bell, James, C.B., D.Sc., Ph.D., F.R.S., F.C.S. The Laboratory, Somerset House, London, W.C.
1891. ‡Bell, James. Bangor Villa, Clive-road, Cardiff.
1871. *Bell, J. Carter, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡Bell, R. Bruce, M.Inst.C.E. 203 St. Vincent-street, Glasgow.
1863. **Bell, Thomas. Oakwood, Epping.*
1867. ‡Bell, Thomas. Belmont, Dundee.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1882. ‡Bellingham, William. 15 Killieser-avenue, Telford Park, Streatham Hill, London, S.W.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford.
1885. ‡Benham, William Blaxland, D.Sc. University College, London, W.C.
1891. §Bennett, Alfred Rosling. 22 St. Alban's-road, Harlesden, London, N.W.
1870. ‡Bennett, Alfred W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. §Bennett, Henry. Bedminster, Bristol.
1887. ‡*Bennett, James M. St. Mungo Chemical Company, Ruckhill, Glasgow.*
1881. §Bennett, John R. 16 West Park, Clifton, Bristol.
1883. *Bennett, Laurence Henry. Bedminster, Bristol.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1870. *Bennett, William. Oak Hill Park, Old Swan, near Liverpool.
1887. ‡Bennion, James A., M.A. 1 St. James'-square, Manchester.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1848. ‡Benson, Starling. Gloucester-place, Swansea.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Cape Town.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1885. *Bent, J. Theodore. 13 Great Cumberland-place, London, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1863. ‡Bentley, Robert, F.L.S. 38 Penywern-road, Earl's Court, London, S.W.
1876. ‡*Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.*
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1887. §Berry, William. Parklands, Bowdon, Cheshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *Bessemer, Sir Henry, F.R.S. Denmark Hill, London, S.E.
1882. *Bessemer, Henry, jun. Town Hill Park, West End, Southampton.
1890. ‡Best, William Woodham. 31 Lyddon-terrace, Leeds.
1883. ‡Betley, Ralph, F.G.S. Mining School, Wigan.
1883. ‡Bettany, Mrs. 33 Oakhurst-grove, East Dulwich-road, London, S.E.
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. The Vicarage, Vowchurch, Hereford.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.

Year of Election.

1890. §Bevington, Miss Mary E. The Elms, Bickley Park, Kent.
1863. ‡Bewick, Thomas John, F.G.S. Suffolk House, Laurence Pountney Hill, London, E.C.
1886. ‡Bickersteth, The Very Rev. E., D.D., Dean of Lichfield. The Deanery, Lichfield.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. Trinity College, Cambridge.
1885. *Bidwell, Shelford, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, London, S.E.
1891. ‡Billups, J. E. 29 The Parade, Cardiff.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, London, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, John E. Electric Works, Sheffield.
1881. §Binnie, Alexander R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, London, S.W.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1880. ‡Bird, Henry, F.C.S. South Down, near Devonport.
1888. *Birley, Miss Caroline. Seedley-terrace, Pendleton, Manchester.
1887. *Birley, H. K. 13 Hyde-road, Ardwick, Manchester.
1871. *Bischof, Gustav. 4 Hart-street, Bloomsbury, London, W.C.
1892. §Bishop, Arthur W., Ph.D. Heriot Watt College, Edinburgh.
1883. ‡Bishop, John le Marchant. 100 Mosley-street, Manchester.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Captain W. H. War Department, Washington, U.S.A.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1889. ‡Black, William. 12 Romulus-terrace, Gateshead.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. Calverley Park, Tunbridge Wells.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John S., M.A., Emeritus Professor of Greek in the Unisity of Edinburgh. 9 Douglas-crescent, Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1888. ‡Blaine, R. S., J.P. Summerhill Park, Bath.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. §Blair, Alexander. 35 Moray-place, Edinburgh.
1892. §Blair, John. 9 Ettrick-road, Edinburgh.
1863. ‡Blake, C. Carter, D.Sc. 28 Townshend-road, Regent's Park, London, N.W.
1886. ‡Blake, Dr. James. San Francisco, California.
1849. *Blake, Henry Wollaston, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1883. *Blake, Rev. J. F., M.A., F.G.S. 40 Loudoun-road, London, N.W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, London, S.E.

Year of Election.

1878. ‡Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1886. ‡Blakie, John. The Bridge House, Newcastle, Staffordshire.
1861. §Blakiston, Matthew, F.R.G.S. Free Hills, Bursledon, Hants.
1887. ‡Blamires, George. Cleckheaton.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡Blanford, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, London, W.
1887. *Bles, A. J. S. Moor End, Kersal, Manchester.
1887. *Bles, Edward J. Moor End, Kersal, Manchester.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1869. *Blomefield, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1880. §Bloxam, G. W., M.A. 3 Hanover-square, London, W.
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. 73 Clarendon-road, Crumpsall, Manchester.
1883. ‡*Blumberg, Dr.* 65 *Hoghton-street, Southport.*
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
1885. ‡Blyth, James, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
Blyth, B. Hall. 135 George-street, Edinburgh.
1883. ‡Blyth, Miss Phœbe. 3 South Mansion House-road, Edinburgh.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1889. †Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, London, E.C.
1884. †Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1881. ‡Bojanowski, Dr. Victor de. 27 Finsbury-circus, London, E.C.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bond, Henry John Hayes, M.D. Cambridge.
1883. §Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, London, N.W.
1871. *Bonney, Rev. Thomas George, D.Sc., LL.D., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. 23 Denning-road, Hampstead, London, N.W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1888. §Boon, William. Coventry.
1890. *Booth, Charles, F.S.S. 2 Talbot-court, Gracechurch-street, London, E.C.
1883. §Booth, James. Hazelhurst, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.
1876. †Booth, Rev. William H. St. Germain's-place, Blackheath, London, S.E.
1883. ‡Boothroyd, Benjamin. Rawlinson-road, Southport.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.
1876. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S., F.C.S. New University Club, St. James's-street, London, S.W.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Taunton, Somerset.

Year of Election.

1867. ‡Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *Bottomley, James Thomson, M.A., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. §Bottomley, W. B. Ferncliffe, Morecambe.
1876. ‡Bottomley, William, jun. 6 Rokeley-terrace, Hillhead, Glasgow.
1890. §Boulnois, Henry Percy, M.Inst.C.E. Municipal Offices, Liverpool.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, London, S.W.
1883. ‡Bourne, A. G., D.Sc., F.L.S., Professor of Zoology in the Presidency College, Madras.
1889. ‡Bourne, R. H. Fox. 41 Priory-road, Bedford Park, Chiswick.
1866. §Bourne, Stephen, F.S.S. Abberley, Wallington, Surrey.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1884. ‡Bovey, Henry T., M.A., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1870. ‡*Bower, Anthony. Bowersdale, Seaforth, Liverpool.*
1881. *Bower, F. O., F.R.S., F.L.S., Professor of Botany in the University of Glasgow.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1886. ‡Bowlby, Rev. Canon. 101 Newhall-street, Birmingham.
1884. ‡Bowley, Edwin. Burnt Ash Hill, Lee, Kent.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E., F.L.S. West Mount, Halifax, Yorkshire.
1887. §Box, Alfred M. 68 Huntingdon-road, Cambridge.
1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.
1887. ‡*Boyd, Robert. Manor House, Didsbury, Manchester.*
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡Boyle, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1892. §Boys, Charles Vernon, F.R.S., Assistant Professor of Physics in the Royal College of Science, London, S.W.
1872. *Brabrook, E. W., F.S.A., V.P.A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡Brady, George S., M.D., LL.D., F.R.S., F.L.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, Romford, Essex.
1864. ‡Braham, Philip, F.C.S. Bath.
1870. ‡Braidwood, Dr. 35 Park-road South, Birkenhead.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.

Year of Election.

1879. ‡Bramley, Herbert. 6 Paradise-square, Sheffield.
1865. §Bramwell, Sir Frederick J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. 5 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. 1 Cintra-terrace, Hill's-road, Cambridge.
1885. *Bratby, William, J.P. Oakfield Hall, Altrincham, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. 1 Garden-court, Temple, London, E.C.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. ‡Briant, T. Hampton Wick, Kingston-on-Thames.
1886. §Bridge, T. W., M.A., Professor of Zoology in the Mason Science College, Birmingham.
1884. ‡Bridges, C. J. Winnipeg, Canada.
1870. *Bridson, Joseph R. Sawrey, Windermere.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *Brigg, John. Broomfield, Keighley, Yorkshire.
1889. ‡*Brigg, T. H. The Grange, Weston, near Otley, Yorkshire.*
1890. ‡Brigg, W. A. Kildwick Hall, near Keighley, Yorkshire.
1866. *Briggs, Arthur. Rawden Hall, Leeds.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
1868. ‡Brine, Captain Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. ‡Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *Brittain, W. H., J.P. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. Farad Villa, Vanbrugh Hill, Blackheath, London, S.E.
1859. *Brodhurst, Bernard Edward, F.R.C.S., F.L.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. 12 Patten-road, Wandsworth Common, S.W.
1865. ‡Brodie, Rev. Peter Bellinger, M.A., F.G.S. Rowington Vicarage, near Warwick.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. The Gore, Eastbourne.
1878. *Brook, George, F.R.S.E., F.L.S. The University, Edinburgh.
1881. §Brook, Robert G. Rowen-street, St. Helens, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1888. ‡Brooke, Rev. Canon R. E., M.A. 14 Marlborough-buildings, Bath.
1887. §Brooks, James Howard. Green Bank, Monton, Eccles, Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1846. *Brooks, Sir Thomas, Bart. Cranshaw Hall, Rawtenstall, Manchester.

Year of Election.

1887. *Bros, W. Law. Sidcup, Kent.
1883. ‡Brotherton, E. A. Fern Cliffe, Ilkley, Yorkshire.
1886. §Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 14 Dean-street, Birmingham.
1863. *Brown, Alexander Crum, M.D., F.R.S. L. & E., Pres.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. §Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1867. ‡Brown, Charles Gage, M.D., C.M.G. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1887. ‡Brown, George. Cadishead, near Manchester.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1884. ‡Brown, Gerald Culmer. Lachute, Quebec, Canada.
1883. ‡Brown, Mrs. H. Bienz. 26 Ferryhill-place, Aberdeen.
1884. ‡Brown, Harry. University College, London, W.C.
1883. ‡Brown, Mrs. Helen. 52 Grange Loan, Edinburgh.
1870. §Brown, Horace T., F.R.S., F.C.S. 47 High-street, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. 52 Grange Loan, Edinburgh.
1870. *Brown, Professor J. Campbell, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Edenderry House, Newtownbreda, Belfast.
1881. *Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.
1882. *Brown, John. 7 Second-avenue, Sherwood Rise, Nottingham.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Haddington, N.B.
1882. *Brown, Mrs. Mary. 68 Bank-parade, Burnley, Lancashire.
1886. §Brown R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1871. ‡Brown, Robert, M.A., Ph.D., F.L.S., F.R.G.S. Fersley, Rydal-road, Streatham, London, S.W.
1868. ‡Brown, Samuel, M.Inst.C.E., Government Engineer. Nicosia, Cyprus.
1891. §Brown T. Forster, M.Inst.C.E. Guildhall Chambers, Cardiff.
1865. ‡Brown, William. 41A New-street, Birmingham.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1892. §Browne, Harold Crichton. Crindon, Dumfries.
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S. L. & E. 7 Cumberland-terrace, Regent's Park, London, N.W.
1891. §Browne, Montagu, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Sandbrook, Tullow, Co. Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1865. *Browne, William, M.D. Heath Wood, Leighton Buzzard.
1887. ‡Brownell, T. W. 6 St. James's-square, Manchester.
1865. ‡Browning, John, F.R.A.S. 63 Strand, London, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.

Year of Election.

1892. §Bruce, James. 10 Hill-street, Edinburgh.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 21 Delahay-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡Brunton, T. Lauder, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, London, W.
1891. ‡Bruton, Edward Henry. 181 Richmond-road, Cardiff.
1878. §Brutton, Joseph. Yeovil.
1886. *Bryan, G. H. Thornlea, Trumpington-road, Cambridge.
1884. ‡Bryce, Rev. Professor George. The College, Manitoba, Canada.
1859. ‡*Bryson, William Gillespie. Cullen, Aberdeen.*
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §Buchan, Alexander, M.A., LL.D., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1885. *Buchan, William Paton. Fairyknowe, Cambuslang, N.B.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. 12 *Barnard-road, Birkenhead, Cheshire.*
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡Buchanan, John Young, M.A., F.R.S. L. & E. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡*Buckland, Miss A. W.* 54 *Doughty-street, London, W.C.*
1886. *Buckle, Edmund W. 23 Bedford-row, London, W.C.
1864. ‡Buckle, Rev. George, M.A. Wells, Somerset.
1865. *Buckley, Henry. The Upper Boon, Linthurst, near Bromsgrove, Birmingham.
1886. §Buckley, Samuel. Merlewood, Beaver-park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, London, W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, London, W.C.
1869. ‡Bucknill, J. C., M.D., F.R.S. East Cliff House, Bournemouth.
1851. *Buckton, George Bowdler, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Kirton, Albemarle-road, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1871. ‡Bulloch, Matthew. 4 Bothwell-street, Glasgow.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Thackray. 'Journal' Office, New-street, Birmingham.
1886. §Burbury, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, London, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, London, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1884. *Burland, Jeffrey H. 287 University-street, Montreal, Canada.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Colonel Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 132 Sutherland-gardens, Maida Vale, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 11 Belmont-street, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.

Year of Election.

1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1883. ‡Burr, Percy J. 20 Little Britain, London, E.C.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, London, E.C.
1881. §Burroughs, S. M. Snow Hill-buildings, London, E.C.
1883. *Burrows, Abraham. Greenhall, Atherton, near Manchester.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, London, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, London, W.
1866. *Burton, Frederick M., F.G.S. Highfield, Gainsborough.
1889. ‡*Burton, Rev. R. Lingen. Zetland Club, Saltburn-by-the-Sea.*
1892. §Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. St. George's Club, Hanover-square, London, W.
1887. *Bury, Henry. Trinity College, Cambridge.
1878. ‡Butcher, J. G., M.A. 22 Collingham-place, London, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Clydesdale, Windsor.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1887. *Buxton, J. H. Poste Restante, Melbourne, Australia.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, London, S.W.
1883. ‡Buxton, Rev. Thomas, M.A. 19 Westcliffe-road, Birkdale, Southport.
1872. ‡Buxton, Sir Thomas Fowell, Bart., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡Byerley, Isaac, F.L.S. 22 Dingle-lane, Toxteth-park, Liverpool.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. §Byrom, John R. Mere Bank, Fairfield, near Manchester.
1875. ‡Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. §Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡*Caird, Edward B.* 8 *Scotland-street, Glasgow.*
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1875. ‡Caldicott, Rev. J. W., D.D. The Rectory, Shipston-on-Stour.
1886. *Caldwell, William Hay. Birnam, Chaucer-road, Cambridge.
1868. ‡Caley, A. J. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1887. ‡Callaway Charles, M.A., D.Sc., F.G.S. Sandon, Wellington, Shropshire.
1892. §Calvert, A. F. The Mount, Oseney-crescent, Camden-road, London, N.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡Cameron, Sir Charles A., M.D. 15 Pembroke-road, Dublin.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1883. ‡Campbell, H. J. 81 Kirkstall-road, Talfourd Park, Streatham Hill, London, S.W.

Year of Election.

Campbell, Sir Hugh P. H., Bart. 18 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
1876. ‡Campbell, James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald. M.D., F.R.S.E. Albyn-place, Edinburgh.
1862. *Campion, Rev. William M., D.D. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡Cannan, Edwin, M.A., F.S.S. 24 St. Giles's, Oxford.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, London, W.
1880. ‡Capper, Robert. Norfolk House, Norfolk-street, Strand, London, W.C.
1883. ‡Capper, Mrs. R. Norfolk House, Norfolk-street, Strand, London, W.C.
1887. ‡Capstick, John Walton. University College, Dundee.
1873. *Carbutt, Sir Edward Hamer, Bart., M.Inst.C.E. 19 Hyde Park-gardens, London, W.
1883. ‡*Carey-Hobson, Mrs.* 54 *Doughty-street, London, W.C.*
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡*Carmichael, George.* 11 *Dudhope-terrace, Dundee.*
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1884. §Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1888. *Carpmael, Alfred. 1 Copthall-buildings, London, E.C.
1884. *Carpmael, Charles. Toronto, Canada.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡Carruthers, William, F.R.S., F.L.S., F.G.S. British Museum, London, S.W.
1886. ‡Carslake, J. Barham. 30 Westfield-road, Birmingham.
1883. ‡Carson, John. 51 Royal Avenue, Belfast.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 78 Rodney-street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1878. *Cartwright, Ernest H., M.A., M.B. 1 Courtfield-gardens, London, S.W.
1870. §Cartwright, Joshua, M.Inst.C.E., Borough Surveyor. Bury, Lancashire.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, London, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.
1883. ‡Carver, James. Garfield House, Elm-avenue, Nottingham.
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1866. ‡Casella, L. P., F.R.A.S. The Lawns, Highgate, London, N.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Saville Park, Halifax.
1888. ‡Cater, R. B. Avondale, Henrietta Park, Bath.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. Repton Lodge, Harborne, Birmingham.

Year of Election.

1887. §Cawley, George. 'Industries,' 358 Strand, London, W.C.
1886. ‡*Cay, Albert. Ashleigh, Westbourne-road, Birmingham.*
1860. §Cayley, Arthur, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1860. ‡Chadwick, David. The Poplars, Herne Hill, London, S.E.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1883. ‡Chalk, William. 24 Gloucester-road, Birkdale, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡Chambers, Charles, F.R.S. Colába Observatory, Bombay.
1883. ‡Chambers, Mrs. Colába Observatory, Bombay.
1883. ‡Chambers, Charles, jun., Assoc.M.Inst.C.E. Colába Observatory, Bombay.
1842. Chambers, George. High Green, Sheffield.
1868. ‡*Chambers, W. O. Lowestoft, Suffolk.*
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Woodlands, Halifax.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1886. *Chance, John Horner. 40 Augustus-road, Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1877. §Chapman, T. Algernon, M.D. Firbank, Hereford.
1836. Charlesworth, Edward, F.G.S. 277 Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡*Charnock, Richard Stephen, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.*
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1883. ‡Chater, Rev. John. Part-street, Southport.
1884. *Chatterton, George, M.A., M.Inst.C.E. 46 Queen Anne's-gate, London, S.W.
1886. §Chattock, A. P. 15 Lancaster-road, Belsize Park, London, N.W.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1884. ‡Chauveau, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1874. *Chermside, Lieut.-Colonel H. C., R.E., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1879. *Chesterman, W. Clarkehouse-road, Sheffield.
Chichester, The Right Rev. Richard Durnford, D.D., Lord Bishop of. Chichester.

Year of Election.

1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.
1883. §Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 6 Place d'Armes, Ontario, Canada.
1889. ‡Chirney, J. W. Morpeth.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. The Rectory, Beaconsfield R.S.O., Bucks.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. 6 Barrow-road, Streatham Common, London, S.W.
1876. *Chrystal, George, M.A., LL.D., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §Church, A. H., M.A., F.R.S., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1881. ‡Churchill, Lord Alfred Spencer. 16 Rutland-gate, London, S.W.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1876. ‡Clark, David R., M.A. 31 Waterloo-street, Glasgow.
1890. ‡Clark, E. K. 81 Caledonian-road, Leeds.
1877. *Clark, F. J. Street, Somerset.
Clark, George T. 44 Berkeley-square, London, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892. §Clark, James, M.A., Ph.D. Yorkshire College, Leeds.
1892. §Clark, James. Chapel House, Paisley.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 12 Feversham-terrace, York.
1861. ‡Clark, Latimer, F.R.S., M.Inst.C.E. 11 Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1887. §Clarke, C. Goddard. Ingleside, Elm-grove, Peckham, S.E.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. §Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1872. *Clarke, Hyde. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡Clarke, John Henry. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. 62 Nelson-street, Chorlton-on-Medlock, Manchester.
1877. ‡Clarke, Professor John W. University of Chicago, Illinois, U.S.A.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1861. ‡*Clay, Charles, M.D.* 101 *Piccadilly, Manchester.*
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1889. §Clayden, A. W., M.A., F.G.S. Warleigh, Palace-road, Tulse Hill Park, London, S.W.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.

Year of Election.

1850. ‡Cleghorn, Hugh, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §Cleland, John, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1886. ‡Clifford, Arthur. Beechcroft, Edgbaston, Birmingham.
1888. ‡Clifton, The Right Rev. the Bishop of, D.D. Bishop's House, Clifton, Bristol.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. §Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *Clowes, Frank, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. 99 Waterloo-crescent, Nottingham.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne James. Rubislaw Den South, Aberdeen.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1891. *Coates, Henry. Pitcullen House, Perth.
Cobb, Edward. Falkland House, St. Ann's, Lewes.
1884. §Cobb, John. Summerhill, Apperley Bridge, Leeds.
1889. §Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1864. **Cochrane, James Henry. Elm Lodge, Prestbury, Cheltenham.*
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. §Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Fairfield, Heaton, Bolton.
1881. *Coffin, Walter Harris, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1884. *Cohen, B. L. 30 Hyde Park-gardens, London, W.
1887. §Cohen, Julius B. Yorkshire College, Leeds.
1887. ‡Cohen, Sigismund. 111 Portland-street, Manchester.
1853. ‡Colchester, William, F.G.S. Burwell, Cambridge.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1892. §Collet, Miss Clare E. 7 Coleridge-road, London, N.
1892. §Collie, Alexander. Harlaw House, Inverurie.
1887. ‡Collie, Norman. University College, Gower-street, London, W.C.
1887. ‡Collier, Thomas. Ashfield, Alderley Edge, Manchester.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. 69 Great Russell-street, London, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 96 Great Portland-street, London, W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡*Collins, J. H., F.G.S. 4 Clark-terrace, Dulwich Rise, London, S.E.*
1876. ‡Collins, Sir William. 3 Park-terrace East, Glasgow.
1884. §Collins, William J., M.D., B.Sc. Albert-terrace, Regent's Park, London, N.W.

Year of Election.

1892. §Colman, H. G. Mason College, Birmingham.
1868. *Colman, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 9 Victoria-chambers, London, S.W.
1884. ‡Colomb, Sir J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, London, S.W.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡Common, A. A., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.
1891. §Common, J. F. F. 3 Glossop-terrace, Cardiff.
1892. §Comyns, Frank, B.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1852. ‡Connal, Sir Michael. 16 Lynedoch-terrace, Glasgow.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C. Notting Hill House, Belfast.
1881. ‡Conroy, Sir John, Bart., F.R.S. Balliol College, Oxford.
1876. ‡Cook, James. 162 North-street, Glasgow.
1882. ‡Cooke, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, London, S.W.
1876. *Cooke, Conrad W. 28 Victoria-street, London, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1868. ‡Cooke, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1859. *Cooke, His Honour Judge, M.A., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1883. ‡Cooke-Taylor, R. Whateley. Frenchwood House, Preston.
1883. ‡Cooke-Taylor, Mrs. Frenchwood House, Preston.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1888. ‡Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.
1883. ‡Coomer, John. Willaston, near Nantwich.
1884. ‡Coon, John S. 604 Main-street, Cambridge Pt., Massachusetts, U.S.A.
1883. ‡Cooper, George B. 67 Great Russell-street, London, W.C.
1850. ‡Cooper, Sir Henry, M.D. 7 Charlotte-street, Hull.
1838. Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1884. ‡Cooper, Mrs. M. A. West Tower, Marple, Cheshire.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1884. ‡Cope, E. D. Philadelphia, U.S.A.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡Copeland, Ralph, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.
1885. ‡Copland, W., M.A. Tortorston, Peterhead, N.B.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1842. Corbett, Edward. Grange-avenue, Levenshulme, Manchester.
1891. §Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. 31 Mark-lane, London, E.C.
1881. §Cordeaux, John. Eaton Hall, Retford, Nottinghamshire.
1883. *Core, Thomas H. Fallowfield, Manchester.
1870. *Corfield, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College. 19 Savile-row, London, W.
1889. ‡Cornish, Vaughan. Ivy Cottage, Newcastle, Staffordshire.

Year of Election.

1884. *Cornwallis, F. S. W. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 12 Beaufort-buildings East, Bath.
1891. §Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
1891. *Cotsworth, Haldane Gwilt. Sand Park, Shaldon, Devonshire.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. King-street, Manchester.
1874. *Cotterill, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡Cotton, General Frederick C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡Cotton, William. Pennsylvania, Exeter.
1879. ‡Cottrill, Gilbert I. Shepton Mallett, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. ‡Courtauld, John M. Bocking Bridge, Braintree, Essex.
1889. ‡Courtney, F. S. 77 Redcliffe-square, South Kensington, London, S.W.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1876. ‡*Cowan, J. B., M.D.* 4 *Eglinton-crescent, Edinburgh.*
1872. *Cowan, Thomas William, F.L.S., F.G.S. 31 Belsize Park-gardens, London, N.W.
1886. ‡Cowen, Mrs. G. R. 9 The Ropewalk, Nottingham.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.Inst.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Lyndhurst, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. §Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. §Crabtree, William, M.Inst.C.E. Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.
1892. *Craig, George A. 66 Edge-lane, Liverpool.
1884. §Craigie, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, London, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. §Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey, Cheshire.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. The Observatory, Dun Echt, Aberdeen.

Year of Election.

1890. §Crawshaw, Charles B. Bank-terrace, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, London, N.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1885. §Creak, Staff Commander E. W., R.N., F.R.S. 36 Kidbrooke Park-road, Blackheath, London, S.E.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1880. *Crisp, Frank, B.A., LL.B., F.L.S. 5 Lansdowne-road, Notting Hill, London, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. University College, Stephen's Green, Dublin.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, Charles W. 41 Carden-place, Aberdeen.
1885. ‡Crombie, John. 129 Union-street, Aberdeen.
1885. ‡Crombie, John, jun. Daveston, Aberdeen.
1885. ‡Crombie, J. W., M.A. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. ‡Crompton, A. 1 St. James's-square, Manchester.
1886. ‡Crompton, Dickinson W. 40 Harborne-road, Edgbaston, Birmingham.
1887. §Crook, Henry T. 9 Albert-square, Manchester.
1870. ‡*Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.*
1865. §Crookes, William, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1870. ‡Crosfield, C. J. Holmfield, Aigburth, Liverpool.
1870. *Crosfield, William. Annesley, Aigburth, Liverpool.
1890. §Cross, E. Richard, LL.B. Harwood House, New Parks-crescent Scarborough.
1887. §Cross, John. Beaucliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A. Halecote, Grange-over-Sands.
1883. ‡Cross, Rev. Prebendary, LL.B. Part-street, Southport.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1886. ‡Crosskey, Cecil. 117 Gough-road, Birmingham.
1867. §Crosskey, Rev. H. W., LL.D., F.G.S. 117 Gough-road, Birmingham.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1870. *Crossley, Edward, M.P., F.R.A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Ferney Green, Bowness, Ambleside.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry. Bramley Oaks, Croydon.
1883. ‡Crowther, Elon. Cambridge-road, Huddersfield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *Culverwell, Edward P. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.

Year of Election.

1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *Cunningham, Lieut.-Colonel Allan, R.E., A.I.C.E. 19 Palace Gardens-terrace, Kensington, London, W.
1887. ‡Cunningham, David, M.Inst.C.E., F.R.S.E., F.S.S. Harbour-chambers, Dundee.
1877. *Cunningham, D. J., M.D., F.R.S., Professor of Anatomy in Trinity College, Dublin.
1891. §Cunningham, J. H. 4 Magdala-crescent, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1892. §Cunningham, Very Rev. John. St. Mary's College, St. Andrews, N.B.
1885. ‡Cunningham, J. T., B.A. Scottish Marine Station, Granton, Edinburgh.
1869. ‡Cunningham, Robert O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Rev. William, D.D., D.Sc. Trinity College, Cambridge.
1892. §Cunningham, William. 14 Inverleith-gardens, Edinburgh.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1892. §Cunningham-Craig, E. H. Clare College, Cambridge.
1885. ‡Curphey, William S. 15 Bute-mansions, Hill Head, Cardiff.
1892. *Currie, James, jun. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1889. ‡Dagger, John H., F.I.C., F.C.S. Endon, Staffordshire.
1854. ‡Daglish, Robert, M.Inst.C.E. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1889. *Dale, Miss Elizabeth. Westbourne, Buxton, Derbyshire.
1887. ‡Dale, Henry F., F.R.M.S., F.Z.S. Royal London Yacht Club, 2 Savile-row, London, W.
1863. ‡Dale, J. B. South Shields.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, London, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡Danby, T. W., M.A., F.G.S. 1 Westbourne-terrace-road, London, W.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *Darbishire, Robert Dukinfield, B.A., F.G.S. 26 George-street, Manchester.
1876. ‡*Darling, G. Erskine.* 247 *West George-street, Glasgow.*
1884. ‡Darling, Thomas. 99 Drummond-street, Montreal, Canada.
1882. ‡Darwin, Francis, M.A., M.B., F.R.S., F.L.S. Wychfield, Huntingdon-road, Cambridge.

Year of Election.

1881. *Darwin, George Howard, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1882. ‡Darwin, W. E., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 1 Cavendish-crescent, Bath.
1872. ‡Davenport, John T. 64 Marine Parade, Brighton.
1880. *Davey, Henry, M.Inst.C.E. 3 Prince's-street, Westminster, S.W.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, London, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1890. ‡*Davies, Arthur. East Brow Cottage, near Whitby.*
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1887. §Davies, David. 55 Berkley-street, Liverpool.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 28 St. Ermin's Mansions, London, S.W.
1870. *Davis, A. S. Vittoria House, Cheltenham.
1864. ‡Davis, Charles E., F.S.A. 55 Pulteney-street, Bath.
1842. Davis, Rev. David, B.A. Almswood, Evesham.
1882. §Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1873. *Davis, James W., F.G.S., F.S.A. Chevinedge, near Halifax.
1883. ‡Davis, Robert Frederick, M.A. Earlsfield, Wandsworth Common, London, S.W.
1885. *Davis, Rudolf. Almswood, Evesham.
1891. ‡Davis, W. 48 Richmond-road, Cardiff.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡Davison, Charles, M.A. 373 Gillott-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T., F.G.S. Cefn Mawr Hall, Mold, North Wales.
1864. ‡Dawkins, W. Boyd, M.A., F.R.S., F.G.S., F.S.A., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1885. *Dawson, Major H. P., R.A. East Holt, Alverstoke, Gosport.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.
1855. §Dawson, Sir William, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal of McGill University. McGill University, Montreal, Canada.
1859. Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. §Day, J. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *Deacon, G. F., M.Inst.C.E. 19 Warwick-square, London, S.W.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.

Year of Election.

1884. *Debenham, Frank, F.S.S. 26 Upper Hamilton-terrace, London, N.W.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E. 1 Obere Sophienstrasse, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1879. ‡De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1887. ‡*De Meschin, Miss Hannah Constance. Sandycove Castle, Kingstown, Ireland.*
1870. ‡*De Meschin, Thomas, B.A., LL.D. Sandycove Castle, Kingstown, Ireland.*
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1873. ‡Denham, Thomas, J.P. Huddersfield.
1884. ‡Denman, Thomas W. Lamb's-buildings, Temple, London, E.C.
1889. §Denny, Alfred, F.L.S., Professor of Biology in the Firth College, Sheffield.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. Orchard Court, Stevenage.
1874. §De Rance, Charles E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *Derby, The Right Hon. the Earl of, K.G., M.A., LL.D., F.R.S., F.R.G.S., Chancellor of the University of London. St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, London, W.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
1868. ‡Dewar, James, M.A., LL.D., F.R.S. L. & E., F.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Rugby School, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, London, W.
1887. ‡De Winton, Colonel Sir F., K.C.M.G., C.B., D.C.L., LL.D., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *Dew-Smith, A. G., M.A. Trinity College, Cambridge.
1889. ‡Dickinson, A. H. Portland House, Newcastle-upon-Tyne.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund. West Cliff, Preston.
1887. §Dickson, H. N. 3 Marlborough-road, Plymouth.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *Dilke, The Right Hon. Sir Charles Wentworth, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.

Year of Election.

1889. ‡Dinning, William. 41 Eldon-street, Newcastle-upon-Tyne.
1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.
1884. ‡Dix, John William H. Bristol.
1874. *Dixon, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Queen's College, Cork.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.
1888. §Dixon, Edward T. Messrs. Lloyds, Barnetts, & Bosanquets' Bank, 54 St. James's-street, London, S.W.
1886. ‡Dixon, George. 42 Augustus-road, Edgbaston, Birmingham.
1879. *Dixon, Harold B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College, Manchester. Birch Hall, Rusholme, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. University College, Bangor, North Wales.
1885. §Dobbin, Leonard. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.
1892. §Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1878. *Dobson, G. E., M.A., M.B., F.R.S., F.L.S. Adrigole, Spring Grove, Isleworth.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. 32 Union-street, Coventry.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1885. ‡Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1882. ‡Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1861. ‡Donnelly, Colonel, R.E., C.B. South Kensington Museum, London, S.W.
1887. ‡*Donner, Edward, B.A.* 4 *Anson-road, Victoria Park, Manchester.*
1887. ‡Dorning, Elias, M.Inst.C.E., F.G.S. 41 John Dalton-street, Manchester.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1889. ‡*Dorsey, E. B. International Club, Trafalgar-square, London, S.W.*
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Care of H. M. Doughty, Esq., 5 Stone-court, Lincoln's Inn, London, W.C.
1876. *Douglas, Rev. G. C. M., D.D. 18 Royal-crescent West, Glasgow.
1877. *Douglass, Sir James N., F.R.S., M.Inst.C.E. Stella House, Dulwich, London, S.E.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1884. ‡Dove, P. Edward, F.R.A.S., Sec.R.Hist.Soc. 23 Old-buildings, Lincoln's Inn, London, W.C.
1884. ‡Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.

Year of Election.

1884. *Dowling, D. J. Bromley, Kent.
1878. ‡*Dowling Thomas. Claireville House, Terenure, Dublin.*
1857. ‡Downing, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, Joseph Emerson, M.Inst.C.E. 3 Great Queen-street, London, S.W.
1887. §Doxey, R. A. Slade House, Levenshulme, Manchester.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1868. ‡Dresser, Henry E., F.Z.S. 110 Cannon-street, London, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. §Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1887. ‡Dreyfus, Dr. Daisy Mount, Victoria Park, Manchester.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1892. §Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, London, W.
1856. *Ducie, The Right. Hon. Henry John Reynolds Moreton, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1867. *Duff, The Right Hon. Sir Mountstuart Elphinstone Grant-, G.C.S.I., F.R.S., Pres.R.G.S. York House, Twickenham.
1852. ‡Dufferin and Ava, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, London, W.
1883. §Duke, Frederic. Conservative Club, Hastings.
1892. §Dulier, Colonel E., C.B. 27 Sloane-gardens, London, S.W.
1866. *Duncan, James. 9 Mincing-lane, London, E.C.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1891. *Duncan, John, J.P. 42 Park-place, Cardiff.
1880. ‡Duncan, William S. 143 Queen's-road, Bayswater, London, W.
1881. ‡Duncombe, The Hon. Cecil. Nawton Grange, York.
1892. §Dunham, Miss Helen Bliss. Messrs. Morton, Rose & Co., Bartholomew House, London, E.C.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. §Dunn, J. T., M.Sc., F.C.S. High School for Boys, Gateshead-on-Tyne.
1883. ‡Dunn, Mrs. Denton Grange, Gateshead-on-Tyne.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, F. P. University Station, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1890. ‡Dunsford, Follett. Rougemont Villa, Headingley, Leeds.
1885. *Dunstan, Wyndham R., M.A., F.C.S., Lecturer on Chemistry at St. Thomas's Hospital and Professor of Chemistry to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1866. †*Duprey, Perry. Woodberry Down, Stoke Newington, London, N.*

Year of Election.

1869. ‡D'Urban, W. S. M., F.L.S. Moorlands, Exmouth, Devon.
1860. ‡Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
1887. §Durham, William, F.R.S.E. Colthrop House, Thatcham, Berkshire.
1887. ‡Dyason, John Sanford, F.R.G.S., F.R.Met.Soc. Boscobel-gardens, London, N.W.
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1883. ‡Eagar, Rev. Thomas. The Rectory, Ashton-under-Lyne.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1888. ‡Earson, H. W. P. 11 Alexandra-road, Clifton, Bristol.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *Easton, Edward, M.Inst.C.E., F.G.S. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1887. *Eccles, Mrs. S. White Coppice, Chorley, Lancashire.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 6 Park-square, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J. Silchar, Cachar, India.
Eden, Thomas. Talbot-road, Oxton.
1884. *Edgell, R. Arnold, M.A., F.C.S. 66 Warwick-road, South Kensington, London, S.W.
1887. §Edgeworth, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. Athenæum Club, Pall Mall, London, S.W.
1870. *Edmonds, F. B. 6 Furnival's Inn, London, E.C.
1883. ‡Edmonds, William. Wiscombe Park, Honiton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, London, S.W.
1884. *Edmunds, James, M.D. 29 Dover-street, Piccadilly, London, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B. 60 Park-street, Park-lane, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1855. *Edwards, Professor J. Baker, Ph.D., D.C.L. Montreal, Canada.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. Christ Church, Oxford.
1885. *Elgar, Francis, LL.D., M.Inst.C.E., F.R.S.E. 113 Cannon-street, London, E.C.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
1863. ‡*Ellenberger, J. L.* *Worksop.*
1885. ‡Ellingham, Frank. Thorpe St. Andrew, Norwich.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. §Elliott, A. C., D.Sc. Professor of Engineering in University College, Cardiff.
1864. ‡Elliott, E. B. Washington, U.S.A.

Year of Election.

1883. *Elliott, Edwin Bailey, M.A., F.R.S. Queen's College, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1879. ‡Elliott, Joseph W. Post Office, Bury, Lancashire.
1886. §Elliott, Thomas Henry, F.S.S. Board of Agriculture, 4 Whitehall-place, London, S.W.
1877. ‡Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 6 Westbourne-terrace, Hyde Park, London, W.
1883. ‡Ellis, John. 17 Church-street, Southport.
1880. *Ellis, John Henry. Woodland House, Plymouth.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1891. §Ellis, Miss M. A. 2 Nottingham-place, London, W.
1884. ‡Ellis, W. Hodgson. Toronto, Canada.
1869. ‡Ellis, William Horton. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, H. W., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1883. ‡Elwes, George Robert. Bossington, Bournemouth.
1887. §Elworthy, Frederick T. Foxdown, Wellington, Somerset.
1870. *Ely, The Right Rev. Lord Alwyne Compton, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1863. ‡Embleton, Dennis, M.D. 19 Claremont-place, Newcastle-upon-Tyne.
1891. ‡Emerton, Wolseley. Banwell Castle, Somerset.
1891. ‡Emerton, Mrs. Wolseley. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1890. ‡Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡*English, J. T. Wayfield House, Stratford-on-Avon.*
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, LL.D., F.R.S., F.R.C.S., President of, and Emeritus Professor of Surgery in, University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1885. ‡Esselmont, Peter, M.P. 34 Albyn-place, Aberdeen.
1862. *Esson, William, M.A., F.R.S., F.C.S., F.R.A.S. Merton College, and 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Vyrniew House, Talbot-road, Old Trafford, Manchester.
1887. *Estcourt, P. A. Vyrniew House, Talbot-road, Old Trafford, Manchester.
1869. ‡Etheridge, Robert, F.R.S. L. & E., F.G.S., Assistant Keeper (Geological and Palæontological Department) Natural History Museum (British Museum). 14 Carlyle-square, London, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, London, S.W.
1883. §Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.

Year of Election.

1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1889. *Evans, A. H. 9 Harvey-road, Cambridge.
1887. *Evans, Mrs. Alfred W. A. Hillside, New Mills, near Stockport, Derbyshire.
1870. *Evans, Arthur John, F.S.A. 33 Holywell, Oxford.
1865. *Evans, Rev. Charles, M.A. The Rectory, Solihull, Birmingham.
1891. ‡Evans, Franklen. Llwynarthen Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1884. ‡Evans, Horace L. Moreton House, Tyndall's Park, Bristol.
1883. *Evans, James C. Albany-buildings, Lord-street, Southport.
1883. *Evans, Mrs. James C. Albany-buildings, Lord-street, Southport.
1861. *Evans, Sir John, K.C.B., D.C.L., LL.D., D.Sc., Treas.R.S., F.S.A., F.L.S., F.G.S. Nash Mills, Hemel Hempstead.
1881. ‡Evans, Lewis. Llanfyrnach R.S.O., Pembrokeshire.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡Evans, William Llewellin. Guildhall-chambers, Cardiff.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. University College, London, W.C.
1868. *Everett, J. D., M.A., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in Queen's College, Belfast. 5 Princess-gardens, Belfast.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. ‡Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡Ewart, J. Cossar, M.D., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. Glenmachan, Belfast.
1859. *Ewing, Sir Archibald Orr, Bart., M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *Ewing, James Alfred, M.A., B.Sc., F.R.S. L. & E., Professor of Mechanism and Applied Mathematics in the University of Cambridge.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1884. *Eyerman, John. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. ‡Faber, Edmund Beckett. Straylea, Harrogate.
1891. *Faija, Henry, M.Inst.C.E. 2 Great Queen-street, London, S.W.
1884. ‡*Fairbairn, Dr. A. M. Airedale College, Bradford, Yorkshire.*
1892. §Fairbairn, T. The Red House, Cluny-gardens, Edinburgh.
1865. *Fairley, Thomas, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1886. ‡Fairley, William. Beau Desert, Rugeley, Staffordshire.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1886. ‡*Fallon, T. P., Consul General. Australia.*
1883. ‡Fallon, Rev. W. S. 1 St. Alban's-terrace, Cheltenham.
1877. §Faraday, F. J., F.L.S., F.S.S. College-chambers, 17 Brazenose-street, Manchester.
1891. ‡Fards, G. Penarth.
1887. ‡Farmer, Sir James. Hope House, Eccles Old-road, Manchester.
1892. *Farmer, J. Bretland. Magdalen College, Oxford.
1886. ‡Farncombe, Joseph, J.P. Lewes.
1879. *Farnworth, Ernest. Clarence Villa, Penn Fields, Wolverhampton.
1883. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.

Year of Election.

1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. ‡Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *Farrar, Ven. Frederic William, M.A., D.D., F.R.S., Archdeacon of Westminster. 17 Dean's-yard Westminster, S.W.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. Boxley House, Tenterden, Kent.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. Torfels, Weston-super-Mare.
1886. §Felkin, Robert W., M.D., F.R.G.S. 20 Alva-street, Edinburgh.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *Fellows, Frank P., K.S.J.J., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. Keswick, near Belfast.
1883. ‡Fenwick, E. H. 29 Harley-street, London, W.
1890. ‡Fenwick, T. Chapel Allerton, Leeds.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1871. *Ferguson, John, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmouth-terrace, Edinburgh.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1883. ‡Fernald, H. P. Alma House, Cheltenham.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1862. ‡Ferrers, Rev. Norman Macleod, D.D., F.R.S. Caius College Lodge, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College. 34 Cavendish-square, London, W.
1892. §Ferrier, Robert M., B.Sc. College of Science, Newcastle-upon-Tyne.
1882. §Fewings, James, B.A., B.Sc. The Grammar School, Southampton.
1887. ‡Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1869. *Field, Rogers, B.A., M.Inst.C.E. 4 Westminster-chambers, Westminster, S.W.
1887. ‡*Fielden, John C.* 145 *Upper Brook-street, Manchester.*
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
Finch, John. Bridge Work, Chepstow.
1878. *Findlater, William. 22 Fitzwilliam-square, Dublin.
1885. ‡*Findlay, George, M.A.* 50 *Victoria-street, Aberdeen.*
1892. §Findlay, J. R., B.A. 3 Rothesay-terrace, Edinburgh.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡*Finnemore, Rev. J., F.G.S. Aston-road, Birmingham.*
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwich.
1858. ‡*Fishbourne, Admiral E. G., R.N.* 26 *Hogarth-road, Earl's Court-road, London, S.W.*
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.

Year of Election.

1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. ‡Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1879. ‡*Fisher, William. Norton Grange, near Sheffield.*
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. University College, London, W.C.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *Fison, Frederick W., M.A., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡Fitch, J. G., M.A., LL.D. 5 Lancaster-terrace, Regent's Park, London, N.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §Fitzgerald, George Francis, M.A., F.R.S., Professor of Natural and Experimental Philosophy, Trinity College, Dublin.
1885. *Fitzgerald, Professor Maurice, B.A. 37 Botanic-avenue, Belfast.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1888. *Fitzpatrick, Rev. Thomas C. Christ's College, Cambridge.
1865. ‡*Fleetwood, D. J.* 45 *George-street, St. Paul's, Birmingham.*
1881. ‡*Fleming, Rev. Canon James, B.D. The Residence, York.*
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §Fletcher, Alfred E., F.C.S. 13 Christchurch-street, Crouch End, London, N.
1870. ‡Fletcher, B. Edgington. Norwich.
1890. ‡Fletcher, B. Morley. 12 Trevor-square, London, S.W.
1886. ‡*Fletcher, Frank M.*
1892. §Fletcher, George. 59 Wilson-street, Derby.
1869. ‡Fletcher, Lavington E., M.Inst.C.E. Alderley Edge, Cheshire.
1888. *Fletcher, Lazarus, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, London, S.W.
1862. §Flower, Sir William Henry, K.C.B., LL.D., D.C.L., D.Sc., F.R.S., F.L.S., F.G.S., F.R.C.S., Director of the Natural History Departments, British Museum, South Kensington, London. 26 Stanhope-gardens, London, S.W.
1889. ‡Flower, Lady. 26 Stanhope-gardens, London, S.W.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. Helwan, Egypt.
1890. §Flux, A. W., M.A. St. John's College, Cambridge.
1887. ‡Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1891. §Földvary, William. Museum Ring, 10, Buda Pesth.
1881. ‡Foljambe, Cecil G. S., M.P. 2 Carlton House-terrace, Pall Mall, London, S.W.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1880. ‡Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *Forbes, George, M.A., F.R.S. L. & E., M.Inst.C.E. 34 Great George-street, London, S.W.
1883. ‡Forbes, Henry O., F.Z.S., Director of the Canterbury Museum, Christchurch, New Zealand.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1890. ‡Ford, J. Rawlinson. Quarry Dene, Weetwood-lane, Leeds.
1875. *Fordham, H. George, F.G.S. Odsey, Ashwell, Baldock, Herts.
1883. §Formby, R. Formby, near Liverpool.

Year of Election.

1887. ‡Forrest, Sir John, K.C.M.G., F.R.G.S. Perth, Western Australia.
1892. §Forrester, John. Whyte's Causeway, Kirkcaldy.
1867. ‡Forster, Anthony. Finlay House, St. Leonards-on-Sea.
1883. ‡Forsyth, A. R., M.A., F.R.S. Trinity College, Cambridge.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1882. §Forward, Henry. 4 Marine-avenue, Southend.
1870. ‡Forwood, Sir William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, London, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *Foster, Clement Le Neve, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London. Llandudno.
1883. ‡Foster, Mrs. C. Le Neve. Llandudno.
1857. *Foster, George Carey, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 18 Daleham-gardens, Hampstead, London, N.W.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *Foster, Michael, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Shelford, Cambridge.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1888. §Fowler, Gilbert J. Dalton Hall, Manchester.
1892. §Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, London, E.C.
1876. *Fowler, John. 5 Derby-street, Sandyford, Glasgow.
1882. ‡Fowler, Sir John, Bart., K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1884. ‡Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. The Cedars, Warlingham, Surrey.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. 28 Victoria-street, Westminster, S.W.
1883. ‡Fox, Howard, F.G.S. Falmouth.
1847. *Fox, Joseph Hoyland. The Cleve, Wellington, Somerset.
1888. ‡Fox, Thomas. Court, Wellington, Somerset.
1886. ‡Foxwell, Arthur, M.A., M.B. 17 Temple-row, Birmingham.
1881. *Foxwell, Herbert S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
1866. *Francis, G. B. Inglesby, North-road, Hertford.
1884. ‡Francis, James B. Lowell, Massachusetts, U.S.A.
Francis, William, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡Frankland, Edward, M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S. The Yews, Reigate Hill, Surrey.
1887. *Frankland, Percy F., Ph.D., B.Sc., F.R.S., Professor of Chemistry in University College, Dundee.
1889. ‡Franklin, Rev. Canon. Clayton-street West, Newcastle-upon-Tyne.
1882. ‡Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡Fraser, Angus, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James William. 8A Kensington Palace-gardens, London, W.

Year of Election.

1865. *Fraser, John, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡Fraser, Thomas R., M.D., F.R.S. L. & E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1859. *Frazer, Daniel. 127 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *Fream, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1865. ‡*Freeman, James.* 15 *Francis-road, Edgbaston, Birmingham.*
1841. Freeth, Major-General S. 30 Royal-crescent, Notting Hill, London, W.
1884. *Fremantle, The Hon. Sir C. W., K.C.B. Royal Mint, London, E.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., Sec.R.G.S. 1 Savile-row, London, W.
1886. ‡*Freund, Miss Ida. Eyre Cottage, Upper Sydenham, S.E.*
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. ‡Froehlich, The Chevalier. Grosvenor-terrace, Withington, Manchester.
1892. *Frost, Edmund. The Elms, Lasswade, Midlothian.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. ‡Frost, Major H., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. St. James's-chambers, Duke-street, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1872. *Fuller, Rev. A. Pallant, Chichester.
1859. ‡Fuller, Frederick, M.A. 9 Palace-road, Surbiton.
1869. ‡Fuller, George, M.Inst.C.E. 71 Lexham-gardens, Kensington, London, W.
1884. §Fuller, William. Oswestry.
1891. ‡Fulton, Andrew. 23 Park-place, Cardiff.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.
1836. *Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 225 Oxford-street, London, W.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1888. ‡Gallenga, Mrs. Anna. The Falls, Chepstow.
1888. ‡Gallenga, Mrs. A. A. R. The Falls, Chepstow.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡Galloway, W. Cardiff.
1887. *Galloway, W. The Cottage, Seymour-grove, Old Trafford, Manchester.
1860. *Galton, Sir Douglas, K.C.B., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (General Secretary.) 12 Chester-street, Grosvenor-place, London, S.W.

Year of Election.

1860. *Galton, Francis, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡Galton, John C., M.A., F.L.S. 40 Great Marlborough-street, London, W.
1870. §Gamble, Lieut.-Colonel D., C.B. St. Helens, Lancashire.
1889. §Gamble, David, jun. St. Helens, Lancashire.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. ‡*Gamble, J. Sykes, M.A., F.L.S. Surbiton.*
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡*Gamgee, Arthur, M.D., F.R.S. Cambridge.*
1889. ‡Gamgee, John. 6 Lingfield-road, Wimbledon, Surrey.
1883. ‡Gant, Major John Castle. St. Leonards.
1887. ‡Gardiner Walter, M.A., F.R.S., F.L.S. Clare College, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. 25 Northbrook-road, Lee, Kent.
1882. ‡Gardner, John Starkie, F.G.S. 29 Albert Embankment, London, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1888. §Garnett, Frederick Brooksbank, C.B., F.S.S. 4 Argyll-road, Campden Hill, London, W.
1887. *Garnett, Jeremiah. The Grange, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L., Principal of the College of Physical Science, Newcastle-upon-Tyne.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. §Garson, J. G., M.D. 32 Duke-street, St. James's, London, S.W.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1892. §Garvie, James. Springfield-road, New Southgate, London, N.
1889. §Garwood, E. J. Trinity College, Cambridge.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. ‡Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S., M.D. Newton Abbot, Devon.
1892. §Geddes, George H. 8 Douglas-crescent, Edinburgh.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. §Geddes, Professor Patrick. 6 James-court, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡Geikie, Sir Archibald, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. (President.) Geological Survey Office, Jermyn-street, London, S.W.
1871. ‡Geikie, James, LL.D., D.C.L., F.R.S. L. & E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 31 Merchiston-avenue, Edinburgh.
1882. *Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwith.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. Worcester College, Oxford.
1870. *Gervis, Walter S., M.D., F.G.S. Ashburton, Devonshire.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.

Year of Election.

1889. ‡Gibson, Charles, M.D. 8 Eldon-square, Newcastle-upon-Tyne.
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1892. §Gibson, Francis Maitland. 1 Fingal-place, Edinburgh.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., Secretary to the Royal College of Physicians of Edinburgh. 17 Alva-street, Edinburgh.
1892. §Gibson, James. 10 North Mansion House-road, Edinburgh.
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1885. ‡Gibson, John, Ph.D. 15 Hartington-gardens, Edinburgh.
1889. *Gibson, T. G. 2 Eslington-road, Newcastle-upon-Tyne.
1887. ‡Giffen, Robert, C.B., LL.D., F.R.S., V.P.S.S. 44 Pembroke-road, London, S.W.
1888. *Gifford, H. J. Lyston Court, Tram Inn, Hereford.
1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.
1842. Gilbert, Joseph Henry, Ph.D., LL.D., F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. Harpenden, near St. Albans.
1883. ‡Gilbert, Mrs. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 1375 Dorchester-street, Montreal, Canada.
1883. ‡*Gilbert, Thomas. Derby-road, Southport.*
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1882. ‡Giles, Alfred, M.P., M.Inst.C.E. 26 Great George-street, London, S.W.
1878. ‡Giles, Oliver. Crescent Villas, Bromsgrove.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *Gill, David, LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.
1888. §Gill, John Frederick. Douglas, Isle of Man.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1887. ‡Gillett, Charles Edwin. Wood Green, Banbury, Oxford.
1888. ‡Gilliland, E. T. 259 West Seventy-fourth-street, New York, U.S.A.
1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1892. §Gilmour, Matthew A. B. Saffronhall House, Windmill-road, Hamilton, N.B.
1861. *Gilroy, George. Mayfield, Orrell Post, Orrell, near Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1867. ‡Ginsburg, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1884. ‡Gisborne, Frederick Newton. Ottawa, Canada.
1886. *Gisborne, Hartley. Qu'Appelle Station, Assa, N.W.T., Canada.
1883. *Gladstone, Miss. 17 Pembridge-square, London, W.
1883. *Gladstone, Miss E. A. 17 Pembridge-square, London, W.
1850. *Gladstone, George, F.C.S., F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *Gladstone, John Hall, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, London, W.
1890. *Gladstone, Miss Margaret E. 17 Pembridge-square, London, W.
1861. *Glaisher, James, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *Glaisher, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. Trinity College, Cambridge.

Year of Election.

1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *Glazebrook, R. T., M.A., F.R.S. 7 Harvey-road, Cambridge.
1887. ‡*Glazier, Walter H., F.C.S. Courtlands, East Molesey, Surrey.*
1881. *Gleadow, Frederic. 84 Kensington Park-road, London, W.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart, M.A. The Shealing, Wimbledon Common, Surrey.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. 124 Manchester-road, Southport.
1887. ‡Glover, Walter T. Moorhurst, Kersal, Manchester.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1889. ‡Goddard, F. R. 19 Victoria-square, Newcastle-upon-Tyne.
1872. ‡Goddard, Richard. 16 Booth-street, Bradford, Yorkshire.
1886. ‡*Godlee, Arthur. 3 Greenfield-crescent, Edgbaston, Birmingham.*
1887. ‡Godlee, Francis. 51 Portland-street, Manchester.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. ‡Godman, F. Du Cane, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, London, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §Godwin-Austen, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1886. ‡Goldsmid, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. Godfrey House, Hollingbourne.
1881. ‡Goldschmidt, Edward, J.P. Nottingham.
1873. ‡Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1890. *Gonner, E. C. K., M.A., Professor of Political Economy in University College, Liverpool.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1878. ‡*Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.*
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1886. ‡Goodman, F. B. 46 Wheeley's-road, Edgbaston, Birmingham.
1885. ‡Goodman, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1865. ‡Goodman, J. D. Minories, Birmingham.
1884. *Goodridge, Richard E. W. 344 La Salle-avenue, Chicago, Illinois, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1883. ‡Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.
1885. ‡Gordon, General the Hon. Sir Alexander Hamilton. 50 Queen's Gate-gardens, London, S.W.
1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1885. ‡Gordon, Rev. George, LL.D. Birnie, by Elgin, N.B.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. Howley Lodge, 112 Harrow-road, London, W.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1887. ‡Gordon, William John. 3 Lavender-gardens, London, S.W.

Year of Election.

1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1875. *Gotch, Francis, B.A., B.Sc., F.R.S. Professor of Physiology in University College, Liverpool. Holywell Cottage, Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.
1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, Surrey.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1867. *Graham, Sir Cyril C., Bart., C.M.G., F.L.S., F.R.G.S. Travellers' Club, Pall Mall, London, S.W.
1875. ‡Grahame, James. 12 St. Vincent-street, Glasgow.
1892. §Grange, C. Ernest. The Grammar School, Ripon, Yorkshire.
1892. §Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F. Northumberland-chambers, Northumberland-avenue, London, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1890. §Gray, Professor Andrew, M.A., F.R.S.E. University College, Bangor.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Rotherham.
1865. ‡Gray, Charles. Swan Bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1892. *Gray, James H., M.A., B.Sc. The University, Glasgow.
1887. §Gray, Joseph W., F.G.S. Spring Hill, Wellington-road South, Stockport.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. 8 Mount Charles, Belfast.
*Gray, Colonel William. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. 36 Gutter-lane, London, E.C.
1883. ‡Gray, Mrs. W. L. 36 Gutter-lane, London, E.C.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1883. ‡Greathead, J. H., M.Inst.C.E. 15 Victoria-street, London, S.W.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1887. ‡Greaves, H. R. The Orchards, Mill End, Stockport.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, London, N.W.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1889. ‡Green, A. H., M.A., F.R.S., F.G.S., Professor of Geology in the University of Oxford. 137 Woodstock-road, Oxford.
1888. §Green, Joseph R., M.A., B.Sc., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1887. ‡Greene, Friese. 162 Sloane-street, London, S.W.
1887. ‡Greenhalgh, Richard. 1 Temple-gardens, The Temple, London, E.C.

Year of Election.

1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1882. ‡Greenhill, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 3 Staple Inn, London, W.C.
1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, London, N.W.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Poynton, Cheshire.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1889. ‡Greenwell, T. G. Woodside, Sunderland.
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1883. ‡Greenwood, J. G., LL.D. 34 Furness-road, Eastbourne.
1849. ‡Greenwood, William. Stones, Todmorden.
1887. §Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Sir Charles Hutton, K.C.M.G., M.Inst.C.E. 2 Delahay-street, Westminster, S.W.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William. Baldersby, Thirsk.
1892. §Greig, J. 351 Charlewood-terrace, Brixton, London, S.W.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 55 West Cromwell-road, London, S.W.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1870. ‡Grieve, John, M.D. Care of W. L. Buchanan, Esq., 212 St. Vincent-street, Glasgow.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
Griffin, S. F. Albion Tin Works, York-road, London, N.
1859. *Griffith, George, M.A., F.C.S. (Assistant General Secretary.) Druries, Harrow.
1870. ‡Griffith, Rev. Henry, F.G.S. Brooklands, Isleworth, Middlesex.
1884. ‡Griffiths, E. H. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.
1847. ‡Griffiths, Thomas. Bradford-street, Birmingham.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1888. *Grimshaw, James Walter. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1881. ‡Gripper, Edward. Nottingham.
1864. ‡Groom-Napier, Charles Ottley. 18 Elgin-road, St. Peter's Park, London, N.W.
1892. §Grove, Mrs. Lilly. Oxford.
Grove, The Right Hon. Sir William Robert, Knt., M.A., D.C.L., LL.D., F.R.S. 115 Harley-street, London, W.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1863. *Groves, Thomas B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡Grubb, Sir Howard, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1886. ‡Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.

Year of Election.

1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
1887. ‡Guillemard, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1885. ‡Gunn, John. 4 Parkside-terrace, Edinburgh.
1891. ‡Gunn, John. Llandaff House, Llandaff.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡Günther, Albert C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, South Kensington, London, S.W.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1883. ‡Guthrie, Malcolm. 2 Parkfield-road, Liverpool.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡Gwyther, R. F., M.A. Owens College, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1887. ‡Hackett, Henry Eugene. Hyde-road, Gorton, Manchester.
1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *Haddon, Alfred Cort, B.A., F.Z.S., Professor of Zoology in the Royal College of Science, Dublin.
1842. Hadfield, George. Victoria-park, Manchester.
1888. *Hadfield, R. A. Hecla Works, Sheffield.
1870. ‡Haigh, George. Waterloo, Liverpool.
1892. §Haigh, E., M.A. Longton, Staffordshire.
1879. ‡Hake, H. Wilson, Ph.D., F.C.S. Queenwood College, Hants.
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1887. ‡Hale, The Hon. E. J. 9 Mount-street, Manchester.
1872. ‡*Hall, Dr. Alfred.* 8 *Mount Ephraim, Tunbridge Wells.*
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. **Hall, Miss Emily. Burlington House, Spring Grove, Isleworth, Middlesex.*
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, London, W.C.
1854. *Hall, Hugh Fergie, F.G.S. Staverton House, Woodstock-road, Oxford.
1887. ‡Hall, John. Springbank, Leftwich, Northwich.
1872. *Hall, Captain Marshall, F.G.S. Easterton Lodge, Parkstone R.S.O., Dorset.
1885. §Hall, Samuel. 19 Aberdeen Park, Highbury, London, N.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *Hall, Townshend M., F.G.S. Orchard House, Pilton, Barnstaple.
1891. *Hallett, George. Cranford, Victoria-road, Penarth, Glamorganshire.
1891. §Hallett, J. H. Maindy Lodge, Cardiff.
1873. *Hallett, T. G. P., M.A. Claverton Lodge, Bath.
1888. §Halliburton, W. D., M.D., F.R.S. 9 Ridgmount-gardens, Gower-street, London, W.C.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1886. ‡*Hambleton, G. W.* 23 *Bryanston-street, Portman-square, London, W.*
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Holmeside, Hazelwood, Derby.

Year of Election.

1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 1A Albyn-place, Aberdeen.
1869. ‡Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1888. *Hammond, Anthony, J.P. 10 Royal-crescent, Bath.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1881. *Hammond, Robert. Hilldrop, Highgate, London, N.
1892. §Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. ‡Hance, Edward M., LL.B. 15 Pelham-grove, Sefton Park, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, London, S.W.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, E.C.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. §Hannaford, E. C. 2573 St. Catherine-street, Montreal, Canada.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1886. §Hansford, Charles. 3 Alexandra-terrace, Dorchester.
1859. *Harcourt, A. G. Vernon, M.A., D.C.L., LL.D., F.R.S., F.C.S. (General Secretary.) Cowley Grange, Oxford.
1890. *Harcourt, L. F. Vernon, M.Inst.C.E. 6 Queen Anne's-gate, London, S.W.
1886. *Hardcastle, Basil W., F.S.S. Beechenden, Hampstead, London, N.W.
1884. *Hardcastle, Norman C., M.A., LL.D., F.S.A. Downing College, Cambridge.
1892. §Harden, Arthur. Ashville, Upper Chorlton-road, Manchester.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrook House, Exeter.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1886. ‡Hardman, John B. St. John's, Hunter's-lane, Birmingham.
1880. ‡*Hardy John.* 118 *Embden-road, Manchester.*
1838. *Hare, Charles John, M.D. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. §Harker, Alfred, M.A., F.G.S. St. John's College, Cambridge.
1876. ‡Harker, Allen, F.L.S., Professor of Natural History in the Royal Agricultural College, Cirencester.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton, Sussex.
1883. *Harley, Miss Clara. The Quintic, Savile Park, Halifax, Yorkshire.
1862. *Harley, George, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, London, W.C.
1862. *Harley, Rev. Robert, M.A., F.R.S., F.R.A.S. The Quintic, Savile Park, Halifax, Yorkshire.
1868. *Harmer, F. W., F.G.S. Oakland House, Cringleford, Norwich.

Year of Election.

1881. *Harmer, Sidney F., M.A., B.Sc. King's College, Cambridge.
1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., Professor of Chemistry and Mineralogy in McGill University, Montreal. Wallbrac-place, Montreal, Canada.
1872. *Harris, Alfred. Lunefield, Kirkby Lonsdale, Westmoreland.
1888. ‡Harris, C. T. 4 Kilburn Priory, London, N.W.
1842. *Harris, G. W., M.Inst.C.E. Mount Gambier, South Australia.
1889. §Harris, H. Graham, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1884. ‡Harris, Miss Katherine E. 73 Albert Hall-mansions, Kensington-gore, London, S.W.
1888. ‡Harrison, Charles. 20 Lennox-gardens, London. S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1864. ‡Harrison, George. Barnsley, Yorkshire.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *Harrison, James Park, M.A. 22 Connaught-street, Hyde Park, London, W.
1892. §Harrison, John. Rockville, Napier-road, Edinburgh.
1889. §Harrison, J. C. Oxford House, Castle-road, Scarborough.
1870. ‡Harrison, Reginald, F.R.C.S. 6 Lower Berkeley-street, Portman-square, London, W.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. §Harrison, Rev. S. N. Ramsay, Isle of Man.
1886. ‡Harrison, W. Jerome, F.G.S. 365 Lodge-road, Hockley, Birmingham.
1885. ‡Hart, Charles J. 10 Calthorpe-road, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.R.S.L. & E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1890. *Hartnell, Wilson. 8 Blenheim-terrace, Leeds.
1886. *Hartog, Professor M. M., D.Sc. Queen's College, Cork.
1887. §Hartog, P. J., B.Sc. Owens College, Manchester.
1885. ‡*Harvey, Surgeon-Major Robert, M.D. Calcutta.*
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1882. ‡Haslam, George James, M.D. Owens College, Manchester.
1875. *Hastings, G. W. Barnard's Green House, Malvern.
1889. ‡Hatch, Dr. F. H., F.G.S. 28 Jermyn-street, London, S.W.
1857. ‡Haughton, Rev. Samuel, M.A., M.D., D.C.L., LL.D., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Trinity College, Dublin.
1887. *Hawkins, William. 11 Fountain-street, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., M.Inst.C.E., F.G.S. 50 Harrington-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. §Hawksley, Thomas, M.Inst.C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. §Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.

Year of Election.

1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *Hay, Admiral the Right Hon. Sir John C. D., Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1885. **Haycraft, Professor John Berry, M.D., B.Sc., F.R.S.E. Physiological Laboratory, The University, Edinburgh.*
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1869. ‡Hayward, J. High-street, Exeter.
1858. *Hayward, Robert Baldwin, M.A., F.R.S. Harrow.
1888. ‡Hazard, Rowland R. Little Mulgrave House, Hurlingham.
1851. §Head, Jeremiah, M.Inst.C.E., F.C.S. Middlesbrough, Yorkshire.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. §Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1871. §Healey, George. Brantfield, Bowness, Windermere.
1883. *Heap, Ralph, jun. 1 Brick-court, Temple, London, E.C.
1861. *Heape, Benjamin. Northwood, Prestwich, Manchester.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡Heape, Joseph R. 96 Tweedale-street, Rochdale.
1882. *Heape, Walter, M.A. St. Mary's, Trumpington, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1889. ‡Heath, Dr. Westgate-road, Newcastle-upon-Tyne.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Calton Hill, Edinburgh.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1886. ‡Heaton, C. W. 44 Woodstock-road, Bedford Park, Chiswick.
1886. ‡Heaton, Miss Ellen. Woodhouse-square, Leeds.
1865. ‡Heaton, Harry. Harborne House, Harborne, Birmingham.
1892. *Heaton, William H., M.A., Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1884. §Heaviside, Rev. George, B.A., F.R.G.S., F.R.Hist.S. 7 Grosvenor-street, Coventry.
1833. ‡Heaviside, Rev. Canon J. W. L., M.A. The Close, Norwich.
1888. *Heawood, Edward, B.A., F.G.S. 41 Old Elvet, Durham.
1888. *Heawood, Percy Y., Lecturer in Mathematics at Durham University. 41 Old Elvet, Durham.
1855. ‡Hector, Sir James, K.C.M.G., M.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Forster, M.D., F.R.S.E. St. Andrews, N.B.
1869. ‡*Hedgeland, Rev. W. J.* 21 *Mount Radford, Exeter.*
1882. ‡Hedger, Philip. Cumberland-place, Southampton.
1887. *Hedges, Killingworth, M.Inst.C.E. 7 Carteret-street, London, S.W.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-upon-Tyne.
1881. *Held-Shaw, H. S., M.Inst.C.E., Professor of Engineering in University College, Liverpool.
1887. §Hembry, Frederick William, F.R.M.S. Sussex Lodge, Sidcup, Kent.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. 277 Lewisham High-road, London, S.E.

Year of Election.

1883. ‡Henderson, Mrs. A. L. 277 Lewisham High-road, London, S.E.
1891. *Henderson, G. G., D.Sc., M.A., F.C.S., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.
1892. §Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall Mansions, London, S.W.
1885. ‡Henderson, William. Devanha House, Aberdeen.
1892. §Henigan, Richard. Alma-road, The Avenue, Southampton.
1856. ‡Hennessy, Henry G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. Brookvale, Donnybrook, Co. Dublin.
1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute. Central Institution, Exhibition-road, London, S.W.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell. Stratheden House, Hyde Park, London, W.
1884. ‡Henshaw, George H. 43 Victoria-street, Montreal, Canada.
1870. ‡*Henty, William.* 12 *Medina-villas, Brighton.*
1892. §Hepburn, David, M.D., F.R.S.E. The University, Edinburgh.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Dartford, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.
1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.
1892. *Herbertson, Andrew J. University Hall, Edinburgh.
1887. *Herdman, William A., D.Sc., F.R.S., Professor of Natural History in University College, Liverpool.
1891. ‡Hern, S. South Cliff, Marine Parade, Penarth.
1871. *Herschel, Alexander S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham College of Science, Newcastle-upon-Tyne. Observatory House, Slough, Bucks.
1874. §Herschel, Colonel John, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1890. ‡Hewetson, H. Bendelack, M.R.C.S., F.L.S. 11 Hanover-square, Leeds.
1884. §Hewett, George Edwin. Cotswold House, St. John's Wood Park, London, N.W.
1883. ‡Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.
1881. ‡Hey, Rev. William Croser, M.A. Clifton, York.
1882. ‡Heycock, Charles T., B.A. King's College, Cambridge.
1883. §Heyes, Rev. John Frederick, M.A., F.C.S., F.R.G.S. 3 Beaconsfield-villas, Dynham-road, West Hampstead, London, N.W.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1879. ‡Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
1886. §Heywood, Henry, J.P., F.C.S. Witla Court, near Cardiff.
*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1888. ‡Hichens, James Harvey, M.A., F.G.S. The College, Cheltenham.
1881. §Hick, Thomas, B.A., B.Sc. Brighton Grove, Rusholme, Manchester.
1875. ‡Hicks, Henry, M.D., F.R.S., Sec.G.S. Hendon Grove, Hendon, Middlesex, N.W.

Year of Election.

1877. §Hicks, Professor W. M., M.A., D.Sc., F.R.S., Principal of Firth College, Sheffield. Firth College, Sheffield.
1886. ‡Hicks, Mrs. W. M. Duvheved, Endcliffe-crescent, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *Hickson, Sydney J., M.A., D.Sc. Downing College, Cambridge.
1864. *Hiern, W. P., M.A. Castle House, Barnstaple.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡Higgins, Clement, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1854. ‡Higgins, Rev. Henry H., M.A. 29 Falkner-square, Liverpool.
1891. §Higgs, Henry, LL.B. 164 Brixton Hill, London, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
1885. *Hill, Alexander, M.A., M.D. Downing College, Cambridge.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathly, East Grinstead.
1881. *Hill, Rev. Edwin, M.A., F.G.S. The Rectory, Cockfield, R.S.O., Suffolk.
1887. ‡Hill, G. H. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1857. §Hill, John, M.Inst.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1886. ‡Hill, M. J. M., D.Sc., Professor of Pure Mathematics in University College, London.
1881. ‡Hill, Pearson. 50 Belsize Park, London, N.W.
1872. *Hill, Rev. Canon, M.A., F.G.S. Sheering Rectory, Harlow.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *Hillhouse, William, M.A., F.L.S., Professor of Botany in Mason Science College, Birmingham. 95 Harborne-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1858. ‡Hincks, Rev. Thomas, B.A., F.R.S. Stokeleigh, Leigh Woods, Clifton, Bristol.
1870. ‡Hinde, G. J., Ph.D., F.G.S. Avondale-road, Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1886. ‡Hingley, Benjamin, M.P. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡Hingston, William Hales, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1890. *Hirst, James Andus. Adel Tower, Leeds.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1884. ‡Hoadrey, John Chipman. Boston, Massachusetts, U.S.A.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. Livingstone House, 374 Wandsworth-road, London, S.W.
1879. ‡Hobkirk, Charles P., F.L.S. West Riding Union Bank, Dewsbury.
1887. *Hobson, Bernard, B.Sc. Tapton Elms, Sheffield.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.

Year of Election.

1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. ‡Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *Hodgkin, Thomas, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 8 Park-villas, Blackheath, London, S.E.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1854. *Holcroft, George. Tyddyngwladis, Gaullwyd, near Dolgelly, North Wales.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Isaac, M.P. Oakworth House, near Keighley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1857. *Holder, Henry William, M.A. Owens College, Manchester.
1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. §Holgate, Benjamin, F.G.S. Cardigan Villa, Grove-lane, Headingley, Leeds.
1879. ‡Holland, Calvert Bernard. Ebbw Vale, South Wales.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1889. §Hollander, Bernard. Unionist Club, 68 Pall Mall, London, S.W.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth, Middlesex.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡*Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.*
1892. §Holmes, Matthew. Netherby, Lenzie, Scotland.
1889. ‡*Holmes, Ralph, B.A. Hulme Grammar School, Manchester.*
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1887. ‡Holt, Thomas. Atlas Iron Works, Molesworth-street, Rochdale.
1891. *Hood, Archibald, M.Inst.C.E. 42 Newport-road, Cardiff.
1875. *Hood, John. Chesterton, Cirencester.
1847. ‡Hooker, Sir Joseph Dalton, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale.
1892. §Hooker, Reginald H., B.A. Royal Statistical Society, 9 Adelphi-terrace, London, W.C.
1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Rev. Samuel F., M.A. The Vicarage, Blackheath Hill, Greenwich, S.E.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. 14 Airlie-gardens, Campden Hill, London, W.
1884. *Hopkins, Edward M. 3 Upper Berkeley-street, Portman-square, London, W.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1884. *Hopkinson, Charles. 305 Moss-lane East, Manchester.

Year of Election.

1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1870. *Hopkinson, John, M.A., D.Sc., F.R.S. Holmwood, Wimbledon, Surrey.
1871. *Hopkinson, John, F.L.S., F.G.S., F.R.Met.Soc. The Grange, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 29 Charles-street, Cardiff.
Hornby, Hugh. Sandown, Liverpool.
1886. ‡Horne, Edward H. Innisfail, Beulah Hill, Norwood, S.E.
1885. ‡Horne, John, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J., F.R.G.S., F.L.S. Surrey Mount, Forest Hill, London, S.E.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1892. §Horsley, Reginald E., M.B. 46 Heriot-row, Edinburgh.
1884. *Hotblack, G. S. Prince of Wales-road, Norwich.
1868. ‡*Hotson, W. C. Upper King-street, Norwich.*
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1886. ‡Houghton, F. T. S., M.A. 119 Gough-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1858. ‡*Hounsfield, James. Hemsworth, Pontefract.*
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
Hovenden, W. F., M.A. Bath.
1879. *Howard, D. Hungershall Lodge, Tunbridge Wells.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1886. §Howard, James L., D.Sc. 20 Oxford-road, Waterloo, near Liverpool.
1887. *Howard, S. S. Llanishen Rise, near Cardiff.
1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1885. ‡Howden, James C., M.D. Sunnyside, Montrose, N.B.
1889. §Howden, Robert, M.B. University of Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh.
1887. ‡*Howell, J. A. Edward-street, Werneth, Oldham.*
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1891. §Howell, Rev. William Charles, M.A., Vicar of Holy Trinity, High Cross, Tottenham, Middlesex.
1886. §Howes, Professor G. B., F.L.S. Royal College of Science, South Kensington, London, S.W.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, Sir H. H., K.C.I.E., M.P., F.S.A. Bentcliffe, Eccles, Manchester.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §Hoyle, William E., M.A. Owens College, Manchester.

Year of Election.

1888. ‡Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1888. ‡Hudson, C. T., M.A., LL.D., F.R.S. 2 Barton-crescent, Dawlish.
1867. *Hudson, William H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, London, S.W.
1858. *Huggins, William, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. 90 Upper Tulse Hill, Brixton, London, S.W.
1892. §Hughes, Alfred W. Woodside, Musselburgh.
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. ‡Hughes, Miss E. P. Newnham College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1891. §Hughes, Rev. W. Hawker. Jesus College, Oxford.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1891. §Hughes, Thomas. West Wharf, Cardiff.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §Hughes, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1883. ‡Hulke, John Whitaker, F.R.S., F.R.C.S., F.G.S. 10 Old Burlington-street, London, W.
1867. §Hull, Edward, M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the Royal College of Science. 20 Arundel-gardens, Notting Hill, London, W.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1887. *Hummel, Professor J. J. Yorkshire College, Leeds.
1890. ‡Humphrey, Frank W. 63 Prince's-gate, London, S.W.
1884. *Humphreys, A. W. 45 William-street, New York, U.S.A.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *Humphry, Sir George Murray, M.D., F.R.S., Professor of Surgery in the University of Cambridge. Grove Lodge, Cambridge.
1877. *Hunt, Arthur Roope, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-gardens, Cardiff.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1864. ‡Hunt, W. Folkestone.
1875. *Hunt, William. Northcote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael, jun. Greystones, Sheffield.
1869. *Hunter, Rev. Robert, LL.D., F.G.S. Forest Retreat, Staples-road, Loughton, Essex.
1879. ‡Huntington, A. K., F.C.S., Professor of Metallurgy in King's College, London. King's College, London, W.C.
1885. ‡Huntly, The Most Hon. the Marquis of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *Hurst, Charles Herbert. Owens College, Manchester.

Year of Election.

1869. ‡Hurst, George. Bedford.
1882. ‡Hurst, Walter, B.Sc. West Lodge, Todmorden.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
1887. ‡Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Captain E. R., R.E. 24 Waterloo-place, Southampton.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1868. *Hutchison, Robert, F.R.S.E. Barnhill, Brodick, Isle of Arran, N.B.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1857. ‡Hutton, Henry D. 17 Palmerston-road, Dublin.
1887. *Hutton, J. Arthur. 29 Dale-street, Manchester.
1861. *Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡Huxley, The Right Hon. Thomas Henry, Ph.D., LL.D., D.C.L., F.R.S., F.L.S., F.G.S., Professor of Biology in the Royal College of Science, London. Hodeslea, Eastbourne.
Hyde, Edward. Dukinfield, near Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
Ihne, William, Ph.D. Heidelberg.
1884. §Iles, George. 7 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡Ingram, J. K., LL.D., M.R.I.A., Librarian to the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1892. §Ireland, D. W. 10 South Gray-street, Edinburgh.
1892. §Irvine, James. Devonshire-road, Birkenhead.
1892. §Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882. §Irving, Rev. A., B.A., D.Sc., F.G.S. Wellington College, Wokingham, Berks.
1888. §Isaac, J. F. V., B.A. Freshford House, Freshford, Bath.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, London, W.
1891. *Ismay, Thomas, H. 10 Water-street, Liverpool.
1887. §Ito, Tokutaro. 83 Hichikenchio Nichomé, Nagoya, Aichiken, Japan.
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. *Jackson, Professor A. H., B.Sc., F.C.S. Care of Messrs. Wm. Bowen & Co., Collins-street, Melbourne, Australia.
1879. ‡Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.

Year of Election.

1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1883. *Jackson, F. J. 1 Morley-road, Southport.
1883. ‡Jackson, Mrs. F. J. 1 Morley-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Lyme Regis, Dorset.
1886. §Jackson, George. Clareen, Higher Warberry, Torquay.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 67 Upgate, Louth, Lincolnshire.
1869. §Jackson, Moses, J.P. Lansdowne House, Tonbridge.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, Merton-road, South Wimbledon, Surrey.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. 38 Prom. des Anglais, Nice, France.
1865. *Jaffray, Sir John, Bart. Park-grove, Edgbaston, Birmingham.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 8 Courtland-terrace, Merthyr Tydfil.
1891. *James, Charles Russell. Courtland House, Merthyr Tydfil.
1872. ‡James, Christopher. 8 Laurence Pountney-hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1886. *James, Harry Berkeley, F.R.G.S. 16 Ashburn-place, London, S.W.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡James, John. 24 The Parade, Cardiff.
1891. ‡James, John Herbert. Howard House, Arundel-street, Strand, London, W.C.
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1858. ‡James, William C. Woodside, Plymouth.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, London, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. §Jamieson, G. Auldjo. 37 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1889. *Japp, F. R., M.A., LL.D., F.R.S., Professor of Chemistry in the University of Aberdeen.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡Jasper, Henry. Holmedale, New Park-road, Clapham Park, London, S.W.
1886. §Jeffcock, Rev. Prebendary John Thomas, F.S.A. The Rectory, Wolverhampton.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. Winton House, Kelvinside, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. Pump-court, Temple, London, E.C.
1885. ‡Jeffreys, Dr. Richard Parker. Eastwood House, Chesterfield.
1887. §Jeffs, Osmund W. 12 Queen's-road, Rock Ferry, Cheshire.
1881. ‡Jellicoe, C. W. A. Southampton.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, London, S.W.
1880. *Jenkins, Sir John Jones. The Grange, Swansea.
1891. §Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. 17 St. Julian's-road, Kilburn, London, N.W.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. 13 Victoria-street, London, S.W.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.

Year of Election.

Jessop, William, jun. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1891. ‡John, E. Cowbridge, Cardiff.
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. §Johnson, Alexander, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. 3 Victoria-road, Clapham, London, S.W.
1883. ‡Johnson, Edmund Litler. 73 Albert-road, Southport.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1888. ‡Johnson, J. G. Southwood Court, Highgate, London, N.
1875. ‡Johnson, James Henry, F.G.S. 73 Albert-road, Southport.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Samuel George. Municipal Offices, Nottingham.
1890. *Johnson, Thomas, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1883. ‡Johnston, H. H. Tudor House, Champion Hill, London, S.E.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston James. Manor House, Northend, Hampstead, London, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. 6 Latham-street, Preston, Lancashire.
1885. ‡Johnston-Lavis, H. J., M.D., F.G.S. Palazzo Caramanico, Chiatomone, Naples.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.
1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡Jolly, William, F.R.S.E., F.G.S., H.M. Inspector of Schools. St. Andrew's-road, Pollokshields, Glasgow.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.
1888. ‡Joly, John, M.A., D.Sc., F.R.S. 39 Waterloo-road, Dublin.
1881. ‡Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.
1849. ‡Jones, Baynham. Walmer House, Cheltenham.
1887. ‡Jones, Professor D. E., B.Sc. University College, Aberystwith.
1890. §Jones, Rev. Edward, F.G.S. Osbourne-place, Fairfax-road, Prestwich, Lancashire.
1891. ‡Jones, Dr. Evan. Aberdare.
1891. ‡Jones, Evan Rowland. Bonnyrigg, Penarth.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *Jones, G. Hartwell, M.A., Professor of Latin in University College, Cardiff.

Year of Election.

1883. *Jones, George Oliver, M.A. 5 Cook-street, Liverpool.
1884. ‡Jones, Rev. Harry, M.A. 8 York-gate, Regent's Park, London, N.W.
1877. ‡Jones, Henry C., F.C.S. Normal School of Science, South Kensington, London, S.W.
1881. *Jones, J. Viriamu, M.A., B.Sc., Principal of the University College of South Wales and Monmouthshire. Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡Jones, Thomas Rupert, F.R.S., F.G.S. 10 Uverdale-road, King's-road, Chelsea, London, S.W.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1891. ‡Jones, William Lester. 22 Newport-road, Cardiff.
1875. *Jose, J. E. 11 Cressington Park, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1875. *Joule, Benjamin St. John B., J.P. Rothesay, N.B.
1847. ‡Jowett, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1879. ‡Jowitt, A. Hawthorn Lodge, Clarkehouse-road, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.
1848. *Joy, Rev. Charles Ashfield. West Hanney, Wantage, Berkshire.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. *Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 31 Ennerdale-road, Kew.
1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, London, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, London, N.
1888. §Kapp, Gisbert. Erba, Wimbledon Park, Surrey.
1887. ‡Kay, Miss. Hamerlaund, Broughton Park, Manchester.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.
1883. ‡*Kearne, John H. Westcliffe-road, Birkdale, Southport.*
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1884. ‡Keefer, Thomas Alexander. Port Arthur, Ontario, Canada.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1892. §Keiller, Alexander, M.D., LL.D., F.R.S.E. 54 Northumberland-street, Edinburgh.
1887. ‡Kellas-Johnstone, J. F. 35 Crescent, Salford.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1885. §Keltie, J. Scott, Assist.Sec.R.G.S., F.S.S. 1 Savile-row, London, W.
1847. *Kelvin, The Right Hon. Lord, M.A., LL.D., D.C.L., Pres.R.S., F.R.S.E., F.R.A.S., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1877. *Kelvin, Lady. The University, Glasgow.
1887. §Kemp, Harry. 254 Stretford-road, Manchester.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.

Year of Election.

1890. §Kempson, Augustus. Care of Capital and Counties Bank, Northampton.
1891. §Kendall, Percy F., F.G.S. Yorkshire College, Leeds.
1875. ‡Kennedy, Alexander B. W., F.R.S., M.Inst.C.E., Emeritus Professor of Engineering in University College, London. 2 Gloucester-place, Portman-square, London, W.
1884. ‡Kennedy, George L., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.
1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1886. §Kenward, James, F.S.A. 280 Hagley-road, Birmingham.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡Kermode, Philip M. C. Ramsay, Isle of Man.
1892. §Kerr, J. Graham. Gowanbrae, Eskbank, Dalkeith.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1887. ‡Kerr, James. Dunkenhalgh, Accrington.
1883. ‡Kerr, Dr. John. Free Church Training College, Glasgow.
1889. ‡Kerry, W. H. R. Manor House, Poolton, Cheshire.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles A. Villa 'Mon Repos,' Altrincham, Cheshire.
1869. *Kesselmeyer, William Johannes. Villa 'Mon Repos,' Altrincham, Cheshire.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.
1886. §Kidston, Robert, F.R.S.E., F.G.S. 24 Victoria-place, Stirling.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1890. §Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡Kinahan, G. Henry, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. *Kinch, Edward, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1883. *King, Francis. Alabama, Penrith.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Wainsford, Lymington, Hants.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1883. *King, Joseph, jun. 6 Wedderburn-road, Hampstead, London, N.W.
1860. *King, Mervyn Kersteman. 1 Victoria-square, Clifton, Bristol.
1875. *King, Percy L. 5 Clifton Park, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. §King, Sir William. Stratford Lodge, Southsea.
1869. ‡Kingdon, K. Taddiford, Exeter.
1876. §Kingston, Thomas. The Limes, Clewer, near Windsor.
1875. §Kingzett, Charles T., F.C.S. Trevena, Amhurst Park, London, N.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.

Year of Election.

1892. §Kinnear, The Hon. Lord, F.R.S.E. Blair Castle, Culross, N.B.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1860. ‡Kirkman, Rev. Thomas P., M.A., F.R.S. Croft Rectory, near Warrington.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1883. ‡Kirsop, Mrs. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *Kitson, Sir James, Bart., M.P. Gledhow Hall, Leeds.
1886. ‡Klein, Rev. L. Martial. University College, Dublin.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. ‡Knight, J. M. Bushwood, Wanstead, Essex.
1883. ‡*Knight, J. R. 32 Lincoln's Inn-fields, London, W.C.*
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 2 Lauriston Park, Edinburgh.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1887. *Knott, Herbert. Wharf Street Mills, Ashton-under-Lyne.
1887. *Knott, John F. Staveleigh, Stalybridge, Cheshire.
1887. ‡Knott, Mrs. Staveleigh, Stalybridge, Cheshire.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡*Knowles, James. The Hollies, Clapham Common, S.W.*
1870. ‡*Knowles, Rev. J. L. 103 Earl's Court-road, Kensington, London, W.*
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1883. ‡Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. ‡Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
*Knox, George James. 27 Portland-terrace, Regent's Park, London, N.W.
1875. *Knubley, Rev. E. P., M.A. Staveley Rectory, Leeds.
1883. ‡Knubley, Mrs. Staveley Rectory, Leeds.
1892. §Kohn, Dr. Charles A. University College, Liverpool.
1890. *Krauss, John Samuel. Whitecot, Wilmslow, Cheshire.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., Union-square, New York City, U.S.A.
1881. ‡Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1885. *Laing, J. Gerard. 1 Elm-court, Temple, London, E.C.
1870. ‡Laird, H. H. Birkenhead.
1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1882. ‡*Lake, G. A. K., M.D. East Park-terrace, Southampton.*
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Union Club, Trafalgar-square, London, S.W.
1887. ‡Lamb, Horace, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. Burton-road, Didsbury, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡Lambert, Rev. Brooke, LL.B. The Vicarage, Greenwich, Kent, S.E.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1890. ‡Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.

Year of Election.

1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, London, S.E.
1883. ‡Lang, Rev. Gavin. Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1886. *Langley, J. N., M.A., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡Lankester, E. Ray, M.A., LL.D., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 42 Half Moon-street, Piccadilly, London, W.
1880. *Lansdell, Rev. Henry, D.D., F.R.A.S., F.R.G.S. Eyre Cottage, The Grove, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡Lapworth, Charles, LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in the Mason Science College, Birmingham. 13 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡Larmor, Joseph, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1883. §Lascelles, B. P. Harrow.
1870. *Latham, Baldwin, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡*Laughton, John Knox, M.A., F.R.G.S.* 130 *Sinclair-road, West Kensington Park, London, W.*
1891. §Laurie, A. P. King's College, Cambridge.
1888. ‡Laurie, Colonel R. P., C.B., M.P. 35 Eaton-place, London, S.W.
1892. §Laurie, Malcolm, B.A., B.Sc., F.L.S. King's College, Cambridge.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, London, S.W.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
1884. §Law, Robert. Fenny Royd Hall, Hipperholme, Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1889. §Laws, W. G., M.Inst.C.E. 5 Winchester-terrace, Newcastle-upon-Tyne.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1868. *Lawson, M. Alexander, M.A., F.L.S. Ootâcamund, Bombay.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1888. §Layard, Miss Nina F. 1 Park-place, Fonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1883. §Leach, John. Claremont, Levenshulme, Manchester.
1875. ‡Leach, Colonel R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. 6 Sussex-place, Regent's Park, London, N.W.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. *Leatham, Edward Aldam. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1863. ‡Leavers, J. W. The Park, Nottingham.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.

Year of Election.

1872. ‡Lebour, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1883. ‡*Lee, Daniel W. Halton Bank, Pendleton, near Manchester.*
1861. ‡Lee, Henry. Sedgeley Park, Manchester.
1883. ‡*Lee, J. H. Warburton. Rossall, Fleetwood.*
1887. *Lee, Sir Joseph Cooksey. Park Gate, Altrincham.
1891. §Lee, Mark. 8 Llandaff-road, Cardiff.
1884. *Leech, Bosdin T. Oak Mount, Timperley, Cheshire.
1887. ‡Leech, D. J., M.D., Professor of Materia Medica in the Owens College, Manchester. Elm House, Whalley Range, Manchester.
1892. *Lees, Charles H., M.Sc. 6 Heald-road, Rusholme, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1883. **Leese, Miss H. K. Fylde-road Mills, Preston, Lancashire.*
*Leese, Joseph. *Fylde-road Mills, Preston, Lancashire.*
1883. ‡*Leese, Mrs.*
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡Le Feuvre, J. E. Southampton.
1872. ‡Lefevre, The Right Hon. G. Shaw, M.P., F.R.G.S. 18 Bryanston square, London, W.
*Legh, Lieut.-Colonel George Cornwall. High Legh Hall, Cheshire.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. §Lehfeldt, Robert A. Firth College, Sheffield.
1868. ‡Leicester, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡Leigh, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1890. §Leigh, Marshall. 22 Goldsmid-road, Brighton.
1891. §Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1886. ‡Leipner, Adolph, Professor of Botany in University College, Bristol. 38 Hampton Park, Bristol.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. ‡Lemon, James, M.Inst.C.E. 11 The Avenue, Southampton.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. 38 Portland-place, London, W.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1871. ‡Leslie, Alexander, M.Inst.C.E. 72 George-street, Edinburgh.
1890. *Lester, Joseph Henry. Corporation Gas Works, Burnley,
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡Letcher, R. J. Lansdowne-terrace, Walters-road, Swansea.
1887. ‡Leverkus, Otto. The Downs, Prestwich, Manchester.
1890. ‡Levy, J. H. Florence, 12 Abbeville-road South, Clapham Park, London, S.W.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡Lewis, Alfred Lionel. 54 Highbury-hill, London, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, D. Morgan, M.A. University College, Aberystwith.
1891. ‡Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.

Year of Election.

1884. *Lewis, Sir W. T. The Mardy, Aberdare.
1860. ‡Liddell, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1887. ‡Liebermann, L. 54 Portland-street, Manchester.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Weaste Hall, Pendleton, Manchester.
1862. ‡Lilford, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*Limerick, The Right Rev. Charles Graves, Lord Bishop of, D.D., F.R.S., M.R.I.A. The Palace, Henry-street, Limerick.
1887. ‡Limpach, Dr. Crumpsall Vale Chemical Works, Manchester.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, M.Inst.C.E., F.G.S. 74 Shooters Hill-road, Blackheath, London, S.E.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1876. ‡*Linn, James. Geological Survey Office, India-buildings, Edinburgh.*
1883. ‡*Lipscomb, Mrs. Lancelot C. d'A. 95 Elgin-crescent, London, W.*
1883. ‡Lisle, H. Claud. Nantwich.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1888. ‡Lister, J. J. Leytonstone, Essex, E.
1861. *Liveing, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *Liversidge, Archibald, F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry and Mineralogy in the University of Sydney, N.S.W. Care of Messrs. Trübner & Co., Ludgate Hill, London, E.C.
1864. §Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.
1880. ‡Llewelyn, Sir John T. D., Bart. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
1889. ‡Lloyd, Rev. Canon. The Vicarage, Rye Hill, Newcastle-upon-Tyne.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
1886. ‡Lloyd, John Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt. 46 Chatham-street Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Myvod House, Wednesbury.
1854. *Lobley, James Logan, F.G.S., F.R.G.S. City of London College, Moorgate-street, London, E.C.
1892. §Loch, C. S., B.A. 15A Buckingham-street, London, W.C.
1867. **Locke, John. Whitehall Club, London, S.W.*
1892. §Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡Lockyer, J. Norman, F.R.S., F.R.A.S. Royal College of Science, South Kensington, London, S.W.
1886. *Lodge, Alfred, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. *Lodge, Oliver J., D.Sc., LL.D., F.R.S., Professor of Physics in University College, Liverpool. 2 Grove-park, Liverpool.
1889. ‡Logan, William. Langley Park, Durham.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1871. *Long, John Jex. 11 Doune-terrace, Kelvinside, Glasgow.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Coddenham Lodge, Cheltenham.

Year of Election.

1883. ‡Longmaid, William Henry. 4 Rawlinson-road, Southport.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Lord-street, Southport.
1861. *Lord, Edward. Adamroyd, Todmorden.
1889. ‡Lord, Riley. Highfield House, Gosforth, Newcastle-upon-Tyne.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, London, W.
1887. *Love, A. E. H. St. John's College, Cambridge.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 11 Notting Hill-square, London, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse, F.I.C. 75 Clarendon-road, Crumpsall, Manchester.
1892. §Lovibond, J. W. Salisbury, Wiltshire.
1889. ‡Low, Charles W. 84 Westbourne-terrace, London, W.
1867. *Low, James F. Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwyn's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. Hillside, Barry, Cardiff.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. §Lowe, D. T. Heriot's Hospital, Edinburgh.
1861. *Lowe, Edward Joseph, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton Hall, near Chepstow.
1884. ‡Lowe, F. J. Elm-court, Temple, London, E.C.
1886. *Lowe, John Landor, M.Inst.C.E. Engineer's Office, Midland Railway, Derby.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.
1853. *Lubbock, The Right Hon. Sir John, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. Down, Farnborough, Kent.
1881. ‡Lubbock, John B. High Elms, Hayes, Kent.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1889. ‡Luckley, George. 7 Victoria-square, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1875. ‡Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1873. ‡*Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.*
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. §Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Mining Engineering in Yorkshire College. 6 De Grey-road, Leeds.
1874. *Lupton, Sydney, M.A. Grove Cottage, Roundhay, near Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Leonard, F.G.S. 92 Onslow-gardens, London, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. §Lyon, Alexander, jun. 52 Carden-place, Aberdeen.

Year of Election.

1878. ‡*Lyte, Cecil Maxwell. Cotford, Oakhill-road, Putney, S.W.*
1862. *Lyte, F. Maxwell, F.C.S. 60 Finborough-road, London, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *Macadam, William Ivison., F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MacAlister, Donald, M.A., M.D., B.Sc. St. John's College, Cambridge.
1879. §MacAndrew, James J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander, M.P., F.R.G.S. 79 Holland Park, London, W.
1884. ‡Macarthur, Alexander. Winnipeg, Canada.
1884. ‡Macarthur, D. Winnipeg, Canada.
1834. Macaulay, James, A.M., M.D. 25 Carlton-vale, London, N.W.
1840. *MacBrayne, Robert. 65 West Regent-street, Glasgow.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1884. ‡McCausland, Orr. Belfast.
1891. §McClean, Frank, M.A., F.S.S. Rusthall House, Tunbridge Wells.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'Clintock, Admiral Sir Francis L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. **McClure, J. H., F.R.G.S.*
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1892. *McCowan, John, M.A., D.Sc. University College, Dundee.
1892. §McCrae, George. 3 Dick-place, Edinburgh.
1883. ‡McCrossan, James. 92 Huskisson-street, Liverpool.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
1878. ‡*McDonnell, Alexander. St. John's, Island Bridge, Dublin.*
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡MacDonnell, Rev. Canon J. C., D.D. Misterton Rectory, Lutterworth.
1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1884. ‡Macdougall, Alan. Toronto, Canada.
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E. 15 Scotland-street, Edinburgh.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1884. ‡Macfie, K. N., B.A., B.C.L. Winnipeg, Canada.
1854. *Macfie, Robert Andrew. Dreghorn, Colinton, Edinburgh.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1888. ‡MacGeorge, James. 67 Marloes-road, Kensington, London, W.
1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.

Year of Election.

1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. 19 Place d'Armes, Montreal, Canada.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1885. ‡Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.
1886. ‡*McGregor, William. Kohima Lodge, Bedford.*
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 400 Great Western-road, Glasgow.
1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.
1867. *M'Intosh, W. C., M.D., LL.D., F.R.S. L. & E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. ‡McIntyre, John, M.D. Odiham, Hants.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. ‡Mackay, Alexander Howard, B.A., B.Sc. The Academy, Pictoũ, Nova Scotia, Canada.
1885. §Mackay, John Yule, M.D. The University, Glasgow.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S. L. & E., Professor of Physiology in the University of Glasgow. The University, Glasgow.
1883. ‡McKendrick, Mrs. The University, Glasgow.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, London, E.C.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. ‡Mackeson, Henry. Hythe, Kent.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 1 Westbourne-terrace, Hyde Park, London, W.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, London, W.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. §Mackinder, H. J., M.A., F.R.G.S. Christ Church, Oxford.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1889. †McKinley, Rev. D. 33 Milton-street, West Hartlepool.
1891. ‡Mackintosh, A. C. Temple Chambers, Cardiff.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1892. §Maclagan, Sir Douglas, M.D., LL.D., F.R.S.E., Professor of Medical Jurisprudence in the University of Edinburgh. 28 Heriot-row, Edinburgh.
1892. §Maclagan, Philip K. D. 14 Belgrave-place, Edinburgh.
1892. §Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent, Edinburgh.
1873. ‡McLandsborough, John, M.Inst.C.E., F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'Laren, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.
1892. *Maclean, Magnus, M.A., F.R.S.E. The University, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1862. ‡*Macleod, Henry Dunning. 17 Gloucester-terrace, Campden Hill-road, London, W.*

Year of Election.

1868. §M'Leod, Herbert, F.R.S., F.C.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1892. §Macleod Reginald. Woodhall, Midlothian.
1892. §Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, John William, F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Lieut.-General C. A. 20 Nevern-square, South Kensington, London, S.W.
1883. ‡MacMahon, Captain P. A., R.A., F.R.S., Instructor in Mathematics at the Royal Military Academy, Woolwich.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡*Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.*
1888. ‡McMillan, Robert. 20 Aubrey-street, Liverpool.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. ‡McMurrick, J. Playfair. Cincinnati, Ohio, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, Archibald White. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
1886. ‡Macpherson, Lieut.-Colonel J. C., R.E. Ordnance Survey Office, Southampton.
1887. §McRae, Charles, M.A. Royal College of Science, South Kensington, London, S.W.
*Macrory, Edmund, M.A. 2 Ilchester-gardens, Prince's-square, London, W.
1883. ‡*McWhirter, William. 170 Kent-road, Glasgow.*
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 48 Gloucester-place, Portman-square, London, W.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. The Admiralty, Whitehall, London, S.W.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1885. *Maitland, Sir James R. G., Bart. Stirling, N.B.
1883. §Maitland, P. C. 136 Great Portland-street, London, W.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1887. ‡Manchester, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.
1885. ‡Mann, George. 72 Bon Accord-street, Aberdeen.
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C. Whatcombe, Blandford.
1888. ‡Mansergh, James, M.Inst.C.E. 3 Westminster-chambers, London, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1889. ‡Manville, E. 3 Prince's-mansions, Victoria-street, London, S.W.
1887. *March, Henry Colley, M.D. 2 West-street, Rochdale.

Year of Election.

1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. §Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.
1864. ‡Markham, Clements R., C.B., F.R.S., F.L.S., F.R.G.S., F.S.A. 21 Eccleston-square, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *Marr, John Edward, M.A., F.R.S., F.G.S. St. John's College, Cambridge.
1857. ‡Marriott, William, F.C.S. 8 Belgrave-terrace, Huddersfield.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1887. ‡*Marsden, Joseph. Ardenlea, Heaton, near Bolton.*
1884. *Marsden, Samuel. St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. Cressy House, Woodsley-road, Leeds.
1887. ‡Marsh, J. E., B.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *Marshall, Alfred, M.A., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1882. *Marshall, A. Milnes, M.A., M.D., D.Sc., F.R.S., Professor of Zoology in Owens College, Manchester.
1889. ‡Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.
1892. §Marshall, Hugh, D.Sc., F.R.S.E. 1 Lorne-terrace, Edinburgh.
1881. *Marshall, John, F.R.A.S., F.G.S. Church Institute, Leeds.
1890. ‡Marshall, John. Derwent Island, Keswick.
1881. ‡Marshall, John Ingham Fearby. 28 St. Saviourgate, York.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1889. *Marshall, Miss Sophie Elise, B.Sc. 38 Percy-gardens, Tynemouth.
1876. ‡*Marshall, Peter.* 6 *Parkgrove-terrace, Glasgow.*
1886. *Marshall, William Bayley, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *Marshall, William P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §Marten, Edward Bindon. Pedmore, near Stourbridge.
1883. ‡Marten, Henry John. 4 Storey's-gate, London, S.W.
1887. *Martin, Rev. H. A. Laxton Vicarage, Newark.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡Martin, H. Newell, M.A., M.D., D.Sc., F.R.S., Professor of Biology in Johns Hopkins University, Baltimore, U.S.A.
1883. *Martin, John Biddulph, M.A., F.S.S. 17 Hyde Park-gate, London, S.W.
1884. §Martin, N. H., F.L.S. 8 Windsor-crescent, Newcastle-upon-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Lyon House, New Barnet, Herts.
1890. §Martindale, William. 19 Devonshire-street, Portland-place, London, W.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1886. ‡Martineau, Sir Thomas, J.P. West Hill, Augustus-road, Edgbaston, Birmingham.
1883. ‡Marwick, Sir James, LL.D. Killermont, Maryhill, Glasgow.

Year of Election.

1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡Maskelyne, Nevil Story, M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Salthrop, Wroughton, Wiltshire.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1891. §Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. 58 Great King-street, Edinburgh.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.P., M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square, Leeds.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, London, W.
1861. *Mathews, William, M.A., F.G.S. 60 Harborne-road, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡Matthews, James. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-upon-Tyne.
1890. ‡Maund, E. A. 294 Regent-street, London, W.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Kenley, Surrey.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. **Maxwell, Francis.* 4 *Moray-place, Edinburgh.*
1887. ‡Maxwell, James. 29 Princess-street, Manchester.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S., F.R.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, London, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1878. ‡Meath, The Right Rev. C. P. Reichel, D.D., Bishop of. Dundrum Castle, Dublin.
1884. ‡Mecham, Arthur. 11 Newton-terrace, Glasgow.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, London, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *Meldola, Raphael, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, London, W.C.
1867. ‡Meldrum, Charles, C.M.G., LL.D., F.R.S., F.R.A.S. Port Louis, Mauritius.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡Mello, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1881. §Melrose, James. Clifton Croft, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General Count, LL.D. 14 Rue de l'Elysée, Paris.

Year of Election.

1862. ‡Mennell, Henry T. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. §Merivale, John Herman, M.A., Professor of Mining in the College of Science, Newcastle-upon-Tyne.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡Miall, Louis C., F.R.S., F.L.S., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of, Middlesbrough.
1883. ‡*Middleton, Henry. St. John's College, Cambridge.*
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. South Pittsburg, Tennessee.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. §Miles, Morris. Warbourne, Hill-lane, Southampton.
1885. §Mill, Hugh Robert, D.Sc., F.R.S.E., Librarian R.G.S. 109 West End-lane, Hampstead, London, N.W.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1889. *Millar, Robert Cockburn. 56 George-street, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1892. *Millard, William Joseph Kelson, M.D., F.R.G.S. Holmleigh, Rockleaze, Stoke Bishop, Bristol.
1882. ‡Miller, A. J. 12 Cumberland-place, Southampton.
1875. ‡Miller, George. Brentry, near Bristol.
1884. ‡*Miller, Mrs. Hugh. Lauriston-place, Edinburgh.*
1892. §Miller, Hugh, F.R.S.E., F.G.S. 3 Douglas-crescent, Edinburgh.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John. The College, Weymouth.
1861. *Miller, Robert. Cranage Hall, Holmes Chapel, Cheshire.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1868. *Mills, Edmund J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, Glasgow. 60 John-street, Glasgow.
1880. §Mills, Mansfeldt H., M.Inst.C.E. Mansfield Woodhouse, Mansfield.
1834. Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. Inveresk.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *Milne, John, F.R.S., F.G.S., Professor of Mining and Geology in the Imperial College of Engineering, Tokio, Japan. Ingleside, Birdhurst Rise, South Croydon, Surrey.
1885. ‡Milne, J. D. 14 Rubislaw-terrace, Aberdeen.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.
1882. ‡*Milnes, Alfred, M.A., F.S.S.* 30 *Almeric-road, London, S.W.*
1888. ‡*Milsom, Charles.* 69 *Pulteney-street, Bath.*
1880. ‡Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, London, W.

Year of Election.

1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, London, W.
1863. ‡Mitchell, C. Walker. Newcastle-upon-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1868. ‡*Mitchell, John, jun. Pole Park House, Dundee.*
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1879. ‡Mivart, St. George, Ph.D., M.D., F.R.S., F.L.S., F.Z.S. Hurstcote, Chilworth, Surrey.
1884. ‡*Moat, Robert. Spring Grove, Bewdley.*
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1887. *Mond, Ludwig, F.R.S., F.C.S. 20 Avenue-road, Regent's Park, London, N.W.
1891. *Mond, Robert Ludwig, B.A., F.R.S.E. 20 Avenue-road, Regent's Park, London, N.W.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1882. *Montagu, Samuel, M.P. 12 Kensington Palace-gardens, London, W.
1891. ‡Montefiore, Arthur, F.G.S., F.R.G.S. 6 Marlborough-road, Bedford Park, Chiswick, London.
1892. §Montgomery, Very Rev. J. F., D.D. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1884. ‡Moore, George Frederick. 49 Hardman-street, Liverpool.
1881. §Moore, Henry. Collingham, Maresfield-gardens, Fitzjohn's-avenue, London, N.W.
1891. ‡Moore, John. Lindenwood, Park-place, Cardiff.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
*Moore, John Carrick, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1857. *Moore, Rev. William Prior. Carrickmore, Galway, Ireland.
1877. ‡Moore, William Vanderkemp. 15 Princess-square, Plymouth.
1871. ‡More, Alexander G., F.L.S., M.R.I.A. 74 Leinster-road, Dublin.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡Morgan, Alfred. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, London, S.W.
1891. §Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1885. ‡Morgan, John. 57 Thomson-street, Aberdeen.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1891. ‡Morgan, Sir Morgan. Cardiff.
1882. §Morgan, Thomas. Cross House, Southampton.
1878. ‡Morgan, William, Ph.D., F.C.S. Swansea.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1892. §Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1867. ‡Morison, William R. Dundee.
1891. ‡Morley, H. The Gas Works, Cardiff.

Year of Election.

1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 29 Kylemore-road, West Hampstead, London, N.W.
1889. ‡Morley, The Right Hon. John, LL.D., M.P. 95 Elm Park-gardens, London, S.W.
1881. ‡Morrell, W. W. York City and County Bank, York.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. §Morris, Daniel, M.A., F.L.S. 11 Kew Gardens-road, Kew.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 40 Wellesley-road, Liverpool.
1888. ‡Morris, J. W., F.L.S. The Woodlands, Bathwick Hill, Bath.
1880. ‡Morris, M. I. E. The Lodge, Penclawdd, near Swansea.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. ‡Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., M.Inst.C.E. 5 Victoria-street, Westminster, S.W.
1890. ‡Morrison, Sir George W. Municipal Buildings, Leeds.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1886. ‡Morrison, John T. Scottish Marine Station, Granton, N.B.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §Morton, George H., F.G.S. 209 Edge-lane, Liverpool.
1858. *Morton, Henry Joseph. 2 Westbourne-villas, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. Hook House, Hook, near Winchfield, Hampshire.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1891. ‡*Moss Arthur J., M.B. Penarth, Glamorganshire.*
1878. *Moss, John Francis, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, Richard Jackson, F.C.S., M.R.I.A. St. Aubin's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. Conservative Club, London, S.W.
1892. §Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. Ovenden, Halifax.
1892. *Mostyn, S. G., B.A. Colet House, Talgarth-road, London, W.
1869. §Mott, Albert J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1866. §Mott, Frederick T., F.R.G.S. Birstall Hill, Leicester.
1862. *Mouat, Frederick John, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. Fletcher, M.A., Q.C., F.R.S. 57 Onslow-square, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡Mount-Edgcumbe, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1850. ‡*Mowbray, John T.* 15 *Albany-street, Edinburgh.*
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., B.A., F.C.S. The College, Bath.

Year of Election.

1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1876. *Muir, Sir John, Bart. 6 Park-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, M.A. Caius College, Cambridge.
1876. ‡Muir, Thomas, M.A., LL.D., F.R.S.E. Beechcroft, Bothwell, Glasgow.
1884. *Muir, William Ker. Detroit, Michigan, U.S.A.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. Cowley-street, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. Mason College, Birmingham.
1884. *Muirhead-Paterson, Miss Mary. Laurieville, Queen's Drive, Crosshill, Glasgow.
1883. ‡Mulhall, Michael G. Fancourt, Balbriggan, Co. Dublin.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1891. §Müller, F. Max, M.A., Professor of Comparative Philology in the University of Oxford. Oxford.
1884. *Müller, Hugo, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, London, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡Mundella, The Right Hon. A. J., M.P., F.R.S., F.R.G.S. 16 Elvaston-place, London, S.W.
1876. ‡Munro, Donald, F.C.S. The University, Glasgow.
1885. ‡Munro, J. E. Crawford, LL.D., Professor of Political Economy in Owens College, Manchester.
1883. *Munro, Robert, M.A., M.D. 48 Manor-place, Edinburgh.
1872. *Munster, H. Sillwood Lodge, Brighton.
1864. ‡Murch, Jerom. Cranwells, Bath.
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1855. ‡Murdoch, James B. Capelrig, Mearns, Renfrewshire.
1890. §Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1884. §Murphy, Patrick. Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1869. ‡Murray, Adam. 78 Manor Road, Brockley, S.E.
1891. §Murray, G. R. M., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, London, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡Murray, John, F.R.S.E. 'Challenger' Expedition Office, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. §Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 34 Clayton-street, Newcastle-on-Tyne.
1883. ‡Murray, W. Vaughan. 4 Westbourne-crescent, Hyde Park, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1891. ‡Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *Myres, John L. Swanbourne, Winslow, Buckinghamshire.

1886. §Nagel, D. H., M.A. Trinity College, Oxford.

Year of Election.

1892. *Nairn, Michael B. Kirkcaldy, N.B.
1890. §Nalder, Francis Henry. 16 Red Lion-street, Clerkenwell, London, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡Nares, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. St. Bernard's, Maple-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D., F.C.S. Troy, New York, U.S.A.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. Dalton Hall, Manchester.
1887. ‡Neill, Joseph S. Claremont, Broughton Park, Manchester.
1887. ‡Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1876. ‡Nelson, D. M. 11 Bothwell-street, Glasgow.
1886. ‡Nettlefold, Edward. 51 Carpenter-road, Edgbaston, Birmingham.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡Neville, F. H. Sidney College, Cambridge.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1891. *Newell, W. H. A. 10 Plasturton-gardens, Cardiff.
1886. ‡Newbolt, F. G. Edenhurst, Addlestone, Surrey.
1842. *Newman, Professor Francis William. 15 Arundel-crescent, Weston-super-Mare.
1889. §Newstead, A. H. L., B.A. Roseacre, Epping.
1860. *Newton, Alfred, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1892. §Newton, E. T., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1883. ‡Nias, Miss Isabel. 56 Montagu-square, London, W.
1882. ‡Nias, J. B., B.A. 56 Montagu-square, London, W.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡Nicholson, Sir Charles, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1867. ‡Nicholson, Henry Alleyne, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.
1887. *Nicholson, John Carr. Moorfield House, Headingley, Leeds.
1884. ‡Nicholson, Joseph S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1881. ‡Nicholson, William R. Clifton, York.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885. §Nicol, W. W. J., M.A., D.Sc., F.R.S.E. Mason Science College, Birmingham.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Aberdeen.
1886. ‡*Niven, George. Erkingholme, Coolhurst-road, London, N.*
1877. ‡Niven, James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.

Year of Election.

1884. ‡Nixon, T. Alcock. 33 Harcourt-street, Dublin.
1863. *Noble, Captain Andrew, C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-upon-Tyne.
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1886. §Nock, J. B. Mayfield, Penns, near Birmingham.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1882. ‡Norfolk, F. 16 Carlton-road, Southampton.
1863. §Norman, Rev. Canon Alfred Merle, M.A., D.C.L., F.R.S., F.L.S. Burnmoor Rectory, Fence Houses, Co. Durham.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡Norris, Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, Shropshire.
1881. §North, Samuel William, M.R.C.S., F.G.S. 84 Micklegate, York.
1881. ‡North, William, B.A., F.C.S. 84 Micklegate, York.
1863. *Northbourne, The Right Hon. Lord, F.G.S. 6 Whitehall-gardens, London, S.W.
*Northwick, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
Norton, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1883. ‡*Nunnerley, John.* 46 *Alexandra-road, Southport.*
1887. §Nursey, Perry Fairfax. 161 Fleet-street, London, E.C.
1883. *Nutt, Miss Lilian. Rosendale Hall, West Dulwich, London, S.E.

1882. §Obach, Eugene, Ph.D. 2 Victoria-road, Old Charlton, Kent.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, London, E.C.
1858. *Odling, William, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. ‡*Ogden, Joseph.* 13 *Hythe-villas, Limes-road, Croydon.*
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡Ogilvie, F. Grant, M.A., B.Sc., F.R.S.E. Heriot Watt College, Edinburgh.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., F.R.G.S. Royal Colonial Institute, Northumberland-avenue, London, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡Oldham, Charles. Syrian House, Sale, near Manchester.
1892. §Oldham, H. Yule. Owens College, Manchester.
1853. ‡Oldham, James, M.Inst.C.E. Cottingham, near Hull.

Year of Election.

1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1892. §Oliphant, James. 50 Palmerston-place, Edinburgh.
1863. ‡Oliver, Daniel, F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
1887. ‡Oliver, F. W., D.Sc. 10 Kew Gardens-road, Kew, Surrey.
1883. ‡Oliver, J. A. Westwood. The Liberal Club, Glasgow.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. ‡Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
*Ommanney, Admiral Sir Erasmus, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. 29 Connaught-square, Hyde Park, London, W.
1880. *Ommanney, Rev. E. A. St. Mary's Vicarage, Frome, Somerset.
1887. †O'Neill, Charles. Glen Allan, Manley-road, Alexandra Park, Manchester.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit. Madras.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. ‡Ord, Miss Maria. Fern Lea, Park-crescent, Southport.
1883. ‡Ord, Miss Sarah. Fern Lea, Park-crescent, Southport.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Major R. T., R.E. Gibraltar.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1873. ‡*Osborn, George.* 47 *Kingscross-street, Halifax.*
1887. §O'Shea, L. T., B.Sc. Firth College, Sheffield.
*Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1869. **Osler, Sidney F. Chesham Lodge, Lower Norwood, Surrey, S.E.*
1884. ‡Osler, William, M.D., Professor of the Institutes of Medicine in McGill University, Montreal, Canada.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Sansome-street, San Francisco, U.S.A.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1888. *Owen, Thomas. 8 Alfred-street, Bath.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis, F.R.S., F.S.S. Belton, Great Yarmouth.
1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.

Year of Election.

1889. ‡Palmer, Sir Charles Mark, Bart., M.P. Grinkle Park, Yorkshire.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1878. *Palmer, Joseph Edward. Howth, Co. Dublin.
1887. *Palmer, Miss Mary Kate. Kilburn House, Sherwood, Notts.
1866. §Palmer, William. Kilbourne House, Cavendish Hill, Sherwood, Nottinghamshire.
1872. *Palmer, W. R. 1 The Cloisters, Temple, E.C.
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1890. ‡Pankhurst, R. M., LL.D. 8 Russell-square, London, W.C.
1883. §Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1884. ‡Panton, Professor J. Hoyes, M.A., F.G.S. Ontario Agricultural College, Guelph, Ontario, Canada.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1865. *Parkes, Samuel Hickling, F.L.S. 6 St. Mary's-row, Birmingham.
1864. ‡*Parkes, William.* 23 *Abingdon-street, Westminster, S.W.*
1879. §Parkin, William. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1841. Parnell, Edward A., F.C.S. Ashley Villa, Swansea.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, N.E.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. Elvaston Hall, Newcastle-upon-Tyne.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. ‡Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡Paterson, A. M., M.D. University College, Dundee.
1884. *Paton, David. Johnstone, Scotland.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. 911 Sherbrooke-street, Montreal, Canada.
1883. ‡Paton, Rev. William. The Ferns, Parkside, Nottingham.
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1884. ‡Patterson, Edward Mortimer. Fredericton, New Brunswick, Canada.
1876. §Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1889. ‡*Pattinson, H. L., jun. Felling Chemical Works, Felling-upon-Tyne.*
1863. ‡Pattinson, John, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. ‡Pattison, Samuel Rowles, F.G.S. 11 Queen Victoria-street, London, E.C.
1864. ‡*Pattison, Dr. T. H. London-street, Edinburgh.*
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡Paul, Benjamin H., Ph.D. 1 Victoria-street, Westminster, S.W.
1892. §Paul, J. Balfour. 32 Great King-street, Edinburgh.

Year of Election.

1863. ‡Pavy, Frederick William, M.D., F.R.S. 35 Grosvenor-street, London, W.
1887. ‡Paxman, James. Hill House, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Eversleigh, Somerset-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡Peach, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, London, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *Pearce, Horace, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.
1888. §Pearce, Rev. R. J., D.C.L., Professor of Mathematics in the University of Durham. 7 South Bailey, Durham.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, London, N.W.
1877. ‡*Pearse, J. Walter. Brussels.*
1881. ‡Pearse, Richard Seward. Southampton.
1883. ‡Pearson, Arthur A. Colonial Office, London, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1892. §Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1881. ‡Pearson, Richard. 57 Bootham, York.
1870. ‡Pearson, Rev. Samuel, M.A. Highbury-quadrant, London, N.
1883. *Pearson, Thomas H. Redclyffe, Newton-le-Willows, Lancashire.
1863. §Pease, H. F. Brinkburn, Darlington.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-upon-Tyne.
1883. ‡Peck, John Henry. 52 Hoghton-street, Southport.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1885. ‡Peddie, W. 2 Cameron Park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡Peek, Cuthbert E. Wimbledon House, Wimbledon, Surrey.
1878. *Peek, William. The Manor House, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1884. ‡Pegler, Alfred. Elmfield, Southampton.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.

Year of Election.

1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, Sir John, G.C.M.G., M.P. 18 Arlington-street, London, S.W.
1887. §Pendlebury William H., M.A., F.C.S. 6 Gladstone-terrace, Priory Hill, Dover.
1856. §Pengelly, William, F.R.S., F.G.S. Lamorna, Torquay.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 6 Lovaine-crescent, Newcastle-upon-Tyne.
*Perigal, Frederick. Cambridge Cottage, Kingswood, Reigate.
1868. *Perkin, William Henry, Ph.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡Perkin, William Henry, jun., Ph.D., F.R.S., F.C.S., Professor of Organic Chemistry in Owens College, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, London, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, London, N.W.
1886. ‡Perrin, Mrs. 23 Holland Villas-road, Kensington, London, W.
1879. ‡Perry, James. Roscommon.
1874. *Perry, John, M.E., D.Sc., F.R.S., Professor of Engineering and Applied Mathematics in the Technical College, Finsbury. 31 Brunswick-square, London, W.C.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 5 Fourth-avenue, Brighton.
1882. ‡Pfoundes, Charles. Spring Gardens, London, S.W.
1886. ‡Phelps, Colonel A. 23 Augustus-road, Edgbaston, Birmingham.
1884. ‡Phelps, Charles Edgar. Carisbrooke House, The Park, Nottingham.
1884. ‡Phelps, Mrs. Carisbrooke House, The Park, Nottingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, London, S.W.
1886. ‡Phelps, Mrs. Hamshall, Birmingham.
1863. *Phené, John Samuel, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1892. §Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Lonsdale, Wanstead, Essex.
1863. ‡Philipson, Dr. 7 Eldon-square, Newcastle-upon-Tyne.
1889. ‡Philipson, John. 9 Victoria-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1887. ‡Phillips, H. Harcourt, F.C.S. 18 Exchange-street, Manchester.
1892. §Phillips, J. H. Poole, Dorset.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1890. §Phillips, R. W., M.A., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1868. ‡Phipson, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Lindow Cottage, Lancaster.

Year of Election.

1885. *Pickering, Spencer U., M.A., F.R.S. 48 Bryanston-square, London, W.
1884. *Pickett, Thomas E., M.D. Maysville, Mason County, Kentucky, U.S.A.
1888. *Pidgeon, W. R. 42 Porchester-square. London, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 4 The Grove, Highgate, London, N.
1865. ‡Pike, L. Owen. 201 Maida-vale, London, W.
1873. ‡Pike, W. H. University College, Toronto, Canada.
1857. ‡*Pilkington, Henry M., LL.D., Q.C.* 45 *Upper Mount-street, Dublin.*
1883. ‡*Pilling, R. C. The Robin's Nest, Blackburn.*
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡Pirie, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1884. ‡Pirz, Anthony. Long Island, New York, U.S.A.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, London, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡Pitt, George Newton, M.A., M.D. 34 Ashburn-place, South Kensington, London, S.W.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. ‡Pitt, Sydney. 34 Ashburn-place, South Kensington, London, S.W.
1868. ‡Pitt-Rivers, Lieut.-General A. H. L., D.C.L., F.R.S., F.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.
1872. ‡*Plant, Mrs. H. W.* 28 *Evington-street, Leicester.*
1842. Playfair, The Right Hon. Lord, K.C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡Playfair, Lieut.-Colonel Sir R. L., K.C.M.G., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 31 George-street, Hanover-square, London, W.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *Pochin, Henry Davis, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1846. ‡Pole, William, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1892. §Popplewell, Dr. Charles. 6 Melville-crescent, Edinburgh.
1868. ‡Portal, Wyndham S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. Brechin Lodge, Cambridge-road, Southport.
1886. ‡Porter, Paxton. Birmingham and Midland Institute, Birmingham.
1888. ‡*Porter, Robert. Westfield House, Bloomfield-road, Bath.*
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-upon-Tyne.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.

Year of Election.

1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Portland-terrace, Newcastle-upon-Tyne.
1883. §Potts, John. Thorn Tree House, Chester-road, Macclesfield.
1886. *Poulton, Edward B., M.A., F.R.S., F.L.S. Wykeham House, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Waunarlwydd House, near Swansea.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, Mosley-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1883. ‡Poynting, J. H., M.A., F.R.S., Professor of Physics in the Mason College, Birmingham. 11 St. Augustine's-road, Birmingham.
1884. §Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., D.C.L. Brazenose College, Oxford.
1891. ‡Pratt, Bickerton. Brynderwen, Maindee, Newport, Monmouthshire.
1869. *Preece, William Henry, F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1888. *Preece, W. Llewellyn. Telegraph Department, Midland Railway, Derby.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1892. §Prentice, Thomas. Willow Park, Greenock.
1889. §Preston, Alfred Eley. 14 The Exchange, Bradford, Yorkshire.
*Prestwich, Joseph, M.A., D.C.L., F.R.S., F.G.S., F.C.S. Shoreham, near Sevenoaks.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1856. *Price, Rev. Bartholomew, M.A., D.D., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. Pembroke College, and 11 St. Giles's, Oxford.
1882. ‡Price, John E., F.S.A. 27 Bedford-place, Russell-square, London, W.C.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡Price, L. L. F. R., M.A., F.S.S. Oriel College, Oxford.
1881. §Price, Peter. 12 Windsor-place, Cardiff.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. §Price, William. 40 Park-place, Cardiff.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. ‡*Priestley, John.* 174 *Lloyd-street, Greenheys, Manchester.*
1892. §Prince, Professor Edward E. St. Mungo's College, Glasgow.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1883. ‡*Prince, Thomas. Horsham-road, Dorking.*
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1846. *Pritchard, Rev. Charles, D.D., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1889. *Pritchard, Eric Law. 12 Alwyne-place, Canonbury, London, N.
1876. *Pritchard, Urban, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1888. ‡Probyn, Leslie C. Onslow-square, London, S.W.

Year of Election.

1881. §Procter, John William. Ashcroft, Nunthorpe, York.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1885. ‡Profeit, Dr. Balmoral, N.B.
1863. ‡Proud, Joseph. South Hetton, Newcastle-upon-Tyne.
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. Alvington, Slade-road, Ilfracombe.
1865. ‡*Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.*
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. 42 Cadogan-place, London, S.W.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Ochil, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
1887. §Pumphrey, William. Lyncombe, Bath.
1885. §Purdie, Thomas, B.Sc., Ph.D., Professor of Chemistry in the University of St. Andrews. St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. ‡Purrott, Charles. West End, near Southampton.
1874. ‡Purser, Frederick, M.A. Rathmines, Dublin.
1866. ‡Purser, Professor John, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stafford-place, Oxford-street, London, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883. §Pye-Smith, Arnold. 16 Fairfield-road, Croydon.
1883. §Pye-Smith, Mrs. 16 Fairfield-road, Croydon.
1868. ‡Pye-Smith, P. H., M.D., F.R.S. 54 Harley-street, W.; and Guy's Hospital, London, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, London, S.W.
1887. ‡Rabone, John. Penderell House, Hamstead-road, Birmingham.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡Radford, R. Heber. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. **Radstock, The Right Hon. Lord.* 70 *Portland-place, London, W.*
1888. ‡Radway, C. W. 9 Bath-street, Bath.
1878. ‡Rae, John, M.D., LL.D., F.R.S., F.R.G.S. 4 Addison-gardens, Kensington, London, W.
1887. *Ragdale, John Rowland. The Beeches, Whitefield, Manchester.
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1885. ‡Ramsay, Major. Straloch, N.B.
1863. ‡Ramsay, Alexander, F.G.S. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyllshire.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1867. **Ramsay, W. F., M.D.* 109 *Sinclair-road, West Kensington Park, London, W.*

Year of Election.

1876. *Ramsay, William, Ph.D., F.R.S., F.C.S., Professor of Chemistry in University College, London, W.C.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, London, W.
1887. ‡Ramsbottom, John. Fernhill, Alderley Edge, Cheshire.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry. 6 Ormonde-terrace, Regent's Park, London, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, London, S.W.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1868. *Ransom, Edwin, F.R.G.S. Ashburnham-road, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. Devisdale, Bowdon, Manchester.
Ransome, Thomas. Hest Bank, near Lancaster.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 11 Stone-buildings, Lincoln's Inn, London, W.C.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1892. §Rathbone, Miss May. Backwood, Neston, Cheshire.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1874. ‡Ravenstein, E. G., F.R.G.S., F.S.S. 91 Upper Tulse-hill, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *Rawlinson, Rev. Canon George, M.A. The Oaks, Precincts, Canterbury.
1855. *Rawlinson, Major-General Sir Henry C., Bart., G.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1875. §Rawson, Sir Rawson W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1886. ‡Rawson, W. Stepney, M.A., F.C.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1883. ‡*Ray, Miss Catherine. Mount Cottage, Flask-walk, Hampstead, London, N.W.*
1868. *Rayleigh, The Right Hon. Lord, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.D., M.R.C.S. Queen-street, Lancaster.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. ‡Reade, Thomas Mellard, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1892. §Redgrave, Gilbert R., Assoc.M.Inst.C.E. Grove Lodge, Muswell Hill, London, N.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1888. ‡Rednall, Miss Edith E. Ashfield House, Neston, near Chester.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. 4 Bishopsgate-street Within, London, E.C.

Year of Election.

Redwood, Isaac. Cae Wern, near Neath, South Wales.
1891. ‡Reece, Lewis Thomas. Somerset House, Roath, Cardiff.
1861. ‡Reed, Sir Edward J., K.C.B., M.P., F.R.S. 75 Harrington-gardens, London, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill.
1891. *Reed, Thomas A. Merchants' Exchange, Cardiff.
1891. §Rees, I. Treharne, M.Inst.C.E. The Elms, Penarth.
1891. ‡Rees, Samuel. West Wharf, Cardiff.
1891. ‡Rees, William. 25 Park-place, Cardiff.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, London, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1881. §Reid, Arthur S., B.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *Reid, Clement, F.G.S. 28 Jermyn-street, London, S.W.
1892. §Reid, E. Waymouth, B.A., Professor of Physiology in University College, Dundee.
1889. ‡Reid, George, Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1884. ‡Reid, Rev. James, B.A. Bay City, Michigan, U.S.A.
1892. §Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1850. ‡Reid, William, M.D. Cruivie, Cupar Fife.
1881. ‡Reid, William. 19½ Blake-street, York.
1875. §Reinold, A. W., M.A., F.R.S., Professor of Physical Science in the Royal Naval College, Greenwich, S.E.
1863. ‡Renals, E. 'Nottingham Express' Office, Nottingham.
1891. §Rendell, Rev. J. R. Whinside, Accrington.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. Hooley Lodge, Redhill.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Manchester and Salford Bank, Southport.
1871. ‡Reynolds, James Emerson, M.D., D.Sc., F.R.S., V.P.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *Reynolds, Osborne, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. 23 Lady Barn-road, Fallowfield, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
1887. ‡Rhodes, George W. The Cottage, Victoria Park, Manchester.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1890. §Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888. ‡Rhodes, John George. Warwick House, 46 St. George's-road, London, S.W.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *Richardson, Arthur, M.D. University College, Bristol.
1863. ‡Richardson, Benjamin Ward, M.A., M.D., LL.D., F.R.S. 25 Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 4 Northumberland-avenue, Putney, S.W.

Year of Election.

1882. §Richardson, Rev. George, M.A. The College, Winchester.
1884. *Richardson, George Straker. Isthmian Club, 150 Piccadilly, London, W.
1889. §Richardson, Hugh. Sedbergh School, Sedbergh R.S.O., Yorkshire.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1881. ‡Richardson, W. B. Elm Bank, York.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. ‡Riches T. Harry. 8 Park-grove, Cardiff.
1886. §Richmond, Robert. Leighton Buzzard.
1863. ‡*Richter, Otto, Ph.D.* 407 *St. Vincent-street, Glasgow.*
1868. ‡Ricketts, Charles, M.D., F.G.S. 19 Hamilton-square, Birkenhead.
1877. ‡Ricketts, James, M.D. St. Helens, Lancashire.
*Riddell, Major-General Charles J. Buchanan, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *Rideal, Samuel, D.Sc., F.C.S., F.G.S. 41 Carlyle-square, London, S.W.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1889. §Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1863. *Rigby, Samuel. Fern Bank, Liverpool-road, Chester.
1881. *Rigg, Arthur. 71 Warrington-crescent, London, W.
1883. *Rigg, Edward, M.A. Royal Mint, London, E.
1883. ‡*Rigg, F. F., M.A.* 32 *Queen's-road. Southport.*
1883. *Rigge, Samuel Taylor, F.S.A. Balmoral-place, Halifax.
1892. §Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*Ripon, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1892. §Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1869. *Rivington, John. Babbicombe, near Torquay.
1888. ‡Robb, W. J. Firth College, Sheffield.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *Robbins, John, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1887. *Roberts, Evan. 3 Laurel-bank, Alexandra-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1870. *Roberts, Isaac, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.
1891. ‡Roberts, Rev. J. Crossby, F.R.G.S. 41 Derby-road, East Park, Northampton.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 1 Field-court, Gray's Inn, London, W.C.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1883. ‡Roberts, Sir William, M.D., F.R.S. 8 Manchester-square, London, W.

Year of Election.

1868. *Roberts-Austen, W. Chandler, C.B., F.R.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. Royal Mint, London, E.
1883. ‡Robertson, Alexander. Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1871. ‡Robertson, George, M.Inst.C.E., F.R.S.E. Athenæum Club, London, S.W.
1883. ‡Robertson, George H. Plas Newydd, Llangollen.
1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1892. §Robertson, W. W. 3 Parliament-square, Edinburgh.
1888. *Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, London, N.W.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1886. ‡*Robinson, Edward E. 56 Dovey-street, Liverpool.*
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Beech Hill, Armagh.
1887. ‡Robinson, Henry. 7 Westminster-chambers, London, S.W.
1887. ‡Robinson, James. Akroydon Villa, Halifax, Yorkshire.
1861. ‡Robinson, John, M.Inst.C.E. Atlas Works, Manchester.
1888. §Robinson, John. Engineer's Office, Barry Dock, Cardiff.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, M.Inst.C.E., F.G.S. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1891. §Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, London, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1876. ‡*Robson, Hazleton R. 14 Royal-crescent West, Glasgow.*
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. 12 John-street, Adelphi, London, W.C.
1872. ‡*Rodwell, George F. Marlborough College, Wiltshire.*
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1883. ‡*Rogers, Thomas Stanley, LL.B. 77 Albert-road, Southport.*
1884. *Rogers, Walter M. Lamowa, Falmouth.
1886. ‡Rogers, W. Woodbourne. Wheeley's-road, Edgbaston, Birmingham.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1876. ‡Rollit, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1876. ‡Romanes, George John, M.A., LL.D., F.R.S., F.L.S. 94 St. Aldate's, Oxford.
1892. *Romanes, John. Edinburgh.

Year of Election.

1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. *Roper, W. O. Eadenbreck, Lancaster.
1855. *Roscoe, Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., M.P., F.R.S., F.C.S. 10 Bramham-gardens, London, S.W.
1883. *Rose, J. Holland, M.A. 25 Dalebury-road. Upper Tooting, London, S.W.
1892. §Rose, Hugh. Kilravock Lodge, Blackford-avenue, Edinburgh.
1885. ‡Ross, Alexander. Riverfield, Inverness.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡*Ross, David, LL.D.* 32 *Nelson-street, Dublin.*
1887. ‡Ross, Edward. Marple, Cheshire.
1880. ‡Ross, Captain G. E. A., F.R.G.S. 8 Collingham-gardens, Cromwell-road, London, S.W.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1869. *Rosse, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1891. §Roth, H. Ling. Lightcliffe, near Halifax, Yorks.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 343 Church-street, Toronto, Canada.
1861. †Routh, Edward J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1887. ‡Rowe, Rev. Alfred W., M.A., F.G.S. Felstead, Essex.
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. ‡Rowe, Rev. John. 13 Hampton-road, Forest Gate, Essex.
1877. ‡Rowe, J. Brooking, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1881. *Rowntree, Joseph. 37 St. Mary's, York.
1881. *Rowntree, J. S. The Mount, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1883. ‡Roy, Charles S., M.D., F.R.S., Professor of Pathology in the University of Cambridge. Trinity College, Cambridge.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1888. ‡Roy, Parbati Churn, B.A. Calcutta, Bengal, India.
1875. *Rücker, A. W., M.A., F.R.S., Professor of Physics in the Royal College of Science, London. (General Treasurer.) 19 Gledhow-gardens, South Kensington, London, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonard's-on-Sea.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Queen Anne's-gate, London, S.W.
1884. ‡Runtz, John. Linton Lodge, Lordship-road, Stoke Newington, London, N.
1887. §Ruscoe, John, F.G.S. Ferndale, Gee Cross, near Manchester.
1847. ‡Ruskin, John, M.A., D.C.L., F.G.S. Brantwood, Coniston, Ambleside.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.

Year of Election.

1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1884. ‡Russell, George. 13 Church-road, Upper Norwood, London, S.E.
1890. §Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 10 Fyfield-road, Oxford.
Russell, John. 39 Mountjoy-square, Dublin.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, London, W.
1876. §Russell, R., F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
1852. *Russell, William J., Ph.D., F.R.S., F.C.S., Lecturer on Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1883. *Ruston, Joseph, M.P. Monk's Manor, Lincoln.
1889. ‡Rutherford, Rev. Dr. 6 Eldon-square, Newcastle-upon-Tyne.
1891. §Rutherford, George. Garth House, Taff's Well, Cardiff.
1871. §Rutherford, William, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1879. ‡Ruxton, Vice-Admiral Fitzherbert, R.N., F.R.G.S. 41 Cromwell-gardens, London, S.W.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1889. §Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1886. ‡*Ryland, F. Augustus-road, Edgbaston, Birmingham.*
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1885. §Saint, W. Johnston. 11 Queen's-road, Aberdeen.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1886. §St. Clair, George, F.G.S. 127 Bristol-road, Birmingham.
1887. *Salford, the Right Rev. the Bishop of. Bishop's House, Salford.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡Salmon, Rev. George, D.D., D.C.L., LL.D., F.R.S., Provost of Trinity College, Dublin.
1883. ‡Salmond, Robert G. The Nook, Kingswood-road, Upper Norwood, S.E.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1872. ‡Salvin, Osbert, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1861. *Sandeman, Archibald, M.A. Garry Cottage, Perth.
1883. ‡*Sandeman, E. 53 Newton-street, Greenock.*
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. *Sanders, Charles J. B. Pennsylvania, Exeter.
1884. ‡Sanders, Henry. 185 James-street, Montreal, Canada.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. †Sanderson, J. S. Burdon, M.A., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. (President Elect.) 64 Banbury-road, Oxford.

Year of Election.

1883. ‡Sanderson, Mrs. Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1892. §Sang, William D. 28 Whyte's Causeway, Kirkcaldy, Fife.
1886. §Sankey, Percy E. Hill House, Lyndhurst, Hants.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡Saunders, Howard, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡Saunders, Trelawney W., F.R.G.S. 3 Elmfield on the Knowles, Newton Abbot, Devon.
1884. ‡Saunders, William. Experimental Farm, Ottawa, Canada.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887. §Savage, Rev. E. B., M.A., F.S.A. St. Thomas' Parsonage, Douglas, Isle of Man.
1871. ‡Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1872. *Sawyer, George David. 55 Buckingham-place, Brighton.
1887. §Sayce, Rev. A. H., M.A., D.D. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Holly Bank, Halifax, Yorkshire.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1879. *Schäfer, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. Croxley Green, Rickmansworth.
1883. ‡Schäfer, Mrs. Croxley Green, Rickmansworth.
1888. §Scharff, Robert F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1892. §Schloss, David F. 1 Knaresborough-place, London, S.W.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. ‡Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. 49 Dover-street, Higher Crumpsall, Manchester.
1888. ‡*Scholey, J. Cranefield.* 30 *Sussex-villas, Kensington, London, W.*
Schunck, Edward, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.
1873. *Schuster, Arthur, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, Manchester.
1887. ‡Schwabe, Colonel G. Salis. Portland House, Higher Crumpsall, Manchester.
1847. *Sclater, Philip Lutley, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, London, W.
1883. *Sclater, William Lutley, B.A., F.Z.S. Eton College, Windsor.
1867. ‡Scott, Alexander. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., D.Sc. 4 North Bailey, Durham.
1882. ‡Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. ‡Scott, Miss Charlotte Angus. Lancashire College, Whalley Range, Manchester.
1889. §Scott, D. H., M.A., Ph.D., F.L.S. The Laurels, Bickley, Kent.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
1886. ‡*Scott, Robert.* 161 *Queen Victoria-street, London, E.C.*

Year of Election.

1857. *Scott, Robert H., M.A., F.R.S., F.G.S., F.R.Met.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1884. *Scott, Sydney C. 15 Queen-street, Cheapside, London, E.C.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1890. §Searle, G. F. C., B.A. Peterhouse, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡Sedgwick, Adam, M.A., F.R.S. Trinity College, Cambridge.
1880. ‡Seebohm, Henry, F.R.G.S., F.L.S., F.Z.S. 22 Courtfield-gardens, London, S.W.
1861. *Seeley, Harry Govier, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 25 Palace Gardens-terrace, Kensington, London, W.
1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. ‡Selim, Adolphus. 21 Mincing-lane, London, E.C.
1885. §Semple, Dr. A. United Service Club, Edinburgh.
1887. §Semple, James C., F.R.G.S., M.R.I.A. 2 Marine-terrace, Kingstown, Co. Dublin.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1892. §Semple, William. Gordon's College, Aberdeen.
1888. §Senier, Alfred, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1858. *Senior, George, F.S.S. Old Whittington, Chesterfield.
1888. *Sennett, Alfred R., A.M.Inst.C.E. Temple-chambers, Victoria Embankment, London, E.C.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892. §Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.
1883. ‡*Seville, Miss M. A. Blythe House, Southport.*
1875. ‡*Seville, Thomas. Blythe House, Southport.*
1892. §Seward, A. C., M.A., F.G.S. 33 Chesterton-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 17 St. Charles-square, Ladbroke Grove-road, London, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, London, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡Sharp, David, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1883. ‡Sharples, Charles H., F.C.S. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1887. *Shaw, James B. Holly Bank, Cornbrook, Manchester.

Year of Election.

1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, London, E.C.
1887. §Shaw, Saville. College of Science, Newcastle-upon-Tyne.
1883. *Shaw, W. N., M.A., F.R.S. Emmanuel House, Cambridge.
1883. ‡Shaw, Mrs. W. N. Emmanuel House, Cambridge.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
1884. ‡Sheldon, Professor J. P. Downton College, near Salisbury.
1878. §Shelford, William, M.Inst.C.E. 35A Great George-street, Westminster, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡Shenstone, W. A. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1885. ‡Shepherd, Charles. 1 Wellington-street, Aberdeen.
1890. ‡Shepherd, J. Care of J. Redmayne, Esq., Grove House, Headingley, Leeds.
1883. ‡Shepherd, James. Birkdale, Southport.
1883. §Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. §Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1888. *Shickle, Rev. C. W., M.A. Langridge Rectory, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, London, S.W.
1892. §Shields, John, B.Sc., Ph.D. Dolphingston, Tranent, Scotland.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, London, E.C.
1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, Surrey, S.W.
1887. *Shipley, Arthur E., M.A. Christ's College, Cambridge.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *Shoolbred, James N., M.Inst.C.E., F.G.S. 1 Westminster-chambers, London, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, London, W.C.
1888. §Shoppee, G. A., M.A., LL.D. 61 Doughty-street, London, W.C.
1875. ‡Shore, Thomas W., F.C.S., F.G.S. Hartley Institution, Southampton.
1882. ‡Shore, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. Sunny Bank, Church-lane, Hornsey, London, N.
1889. ‡Sibley, Walter K., B.A., M.B. 7 Harley-street, London, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson. Erlesdene, Bowdon, Cheshire.
1885. *Sidgwick, Henry, M.A., Litt.D., D.C.L., Professor of Moral Philosophy in the University of Cambridge. Hillside, Chesterton-road, Cambridge.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 7 Airlie-gardens, Campden Hill, London, W.
1878. ‡Sigerson, Professor George, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. ‡Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1887. *Simon, Henry. Darwin House, Didsbury, near Manchester.

Year of Election.

1847. ‡Simon, Sir John, K.C.B., D.C.L., F.R.S., F.R.C.S., Consulting Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *Simpson, Alexander R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. ‡Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. ‡Simpson, F. Estacion Central, Buenos Ayres.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡Simpson, Maxwell, M.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
Simpson, William. Bradmore House, Hammersmith, London, W.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1870. *Sinclair, W. P., M.P. Rivelyn, Prince's Park, Liverpool.
1864. *Sircar, The Hon. Mohendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. §Sisley, Richard, M.D. 11 York-street, Portman-square, London, W.
1879. ‡Skertchly, Sydney B. J., F.G.S. 3 Loughborough-terrace, Carshalton, Surrey.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1892. §Skinner, William. 35 George-square, Edinburgh.
1888. §Skrine, H. D., J.P., D.L. Claverton Manor, Bath.
1870. §Sladen, Walter Percy, F.G.S., F.L.S. 13 Hyde Park-gate, London, S.W.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.G.S. Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1860. ‡Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1887. §Small, E. W., M.A., F.G.S. County Council Offices, Newport, Monmouthshire.
1887. §Small, William. Cavendish-crescent North, The Park, Nottingham.
1881. ‡Smallshan, John. 81 Manchester-road, Southport.
1885. §Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William. Nunholme, Dowanhill, Glasgow.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. §Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smieton, John G. 3 Polworth-road, Coventry Park, Streatham, London, S.W.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. §Smith, Adam Gillies, F.R.S.E. 35 Drumsheugh-gardens, Edinburgh.
1892. §Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Wabash College, Crawfordsville, Indiana, U.S.A.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.

Year of Election.

1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, London, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. Christian College, Madras.
1865. ‡Smith, David, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. §Smith, E. Wythe. 66 College-street, Chelsea, London, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1887. ‡Smith, Rev. F. J., M.A. Trinity College, Oxford.
1892. §Smith, Rev. Frederick. 16 Grafton-street, Glasgow.
1885. ‡Smith, Rev. G. A., M.A. 91 Fountainhall-road, Aberdeen.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 49 Beaumont-square, London, E.
1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 54 West Nile-street, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1871. ‡Smith, J. William Robertson, M.A., Lord Almoner's Professor of Arabic in the University of Cambridge.
1883. ‡Smith, M. Holroyd. Fern Hill, Halifax.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡Smith, Robert H., M.Inst.C.E., Professor of Engineering in the Mason Science College, Birmingham.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. §Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, London, W.C.
1887. ‡Smith, Dr. Wilberforce. 14 Stratford-place, London, W.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡Smithells, Arthur, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1892. §Smithson, G. E. T. Tyneside Geographical Society, Barras Bridge, Newcastle-upon-Tyne.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1882. §Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.

Year of Election.

1850. *Smyth, Charles Piazzi, F.R.S.E., F.R.A.S. Clova, Ripon.
1883. ‡Smyth, Rev. Christopher. Firwood, Chalford, Stroud.
1874. ‡Smyth, Henry. Eastern Villa, Newcastle, Co. Down, Ireland.
1878. §Smyth, Mrs. Isabella. Wigmore Lodge, Cullenswood-avenue, Dublin.
1857. *Smyth, John, jun., M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *Snape, H. Lloyd, D.Sc., Ph.D., F.C.S., Professor of Chemistry in University College, Aberystwith.
1888. ‡Snell, Albion T. Brightside, Salusbury-road, Brondesbury, London, N.W.
1887. ‡Snell, Rev. Bernard J., M.A. 5 Park-place, Broughton, Manchester.
1878. §Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1889. ‡Snell, W. H. Lamorna, Oxford-road, Putney, S.W.
1879. *Sollas, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
1892. *Somervail, Alexander. Torquay.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *Sorby, H. Clifton, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1892. §Sorley, James, F.R.S.E. 18 Magdala-crescent, Edinburgh.
1888. ‡Sorley, Professor W. R. University College, Cardiff.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1887. §Sowerbutts, Eli, F.R.G.S. 44 Brown-street, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.
1863. *Spark, H. King, F.G.S. Startforth House, Barnard Castle.
1889. ‡Spence, Faraday. 67 Grey-street, Hexham.
1869. **Spence, J. Berger.* 31 *Lombard-street, London, E.C.*
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1881. ‡*Spencer, Herbert E. Lord Mayor's Walk, York.*
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newburn, Newcastle-upon-Tyne.
1861. ‡*Spencer, John Frederick.* 28 *Great George-street, London, S.W.*
1891. *Spencer, Richard Evans. 6 Working-street, Cardiff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. *Spiller, John, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1864. *Spottiswoode, W. Hugh, F.C.S. 41 Grosvenor-place, London, S.W.
1854. *Sprague, Thomas Bond, M.A., F.R.S.E. 26 St. Andrew-square, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, London, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Tamworth.
Square, Joseph Elliot. 147 Maida Vale, London, W.

Year of Election.

1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. 6 Heathfield-terrace, Chiswick, Middlesex.
1890. ‡*Stables, James. Lane Ends, Horsham.*
1888. *Stacy, J. Sargeant. 7 and 8 Paternoster-row, London, E.C.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. §Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, Bromley, Kent.
1865. ‡STANFORD, EDWARD C. C., F.C.S. Glenwood, Dalmuir, N.B.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, Surrey, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1883. ‡Stapley, Alfred M. Marion-terrace, Crewe.
1876. ‡Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Shipley, Yorkshire.
1881. ‡Stead. W. H. Orchard-place, Blackwall, London, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, London, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. §Stebbing, Thomas R. R. Fernbank, Millport, by Glasgow.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1887. ‡Steinthal, Rev. S. Alfred. 81 Nelson-street, Manchester.
1887. ‡Stelfox, John L. 6 Hilton-street, Oldham, Manchester.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1891. *Stephens, Miss Gulielma. Girtups, Bridport.
1884. *Stephens, W. Hudson. Lowville (P.O.), State of New York, U.S.A.
1879. *STEPHENSON, Sir HENRY, J.P. The Glen, Sheffield.
1870. *Stevens, Miss Anna Maria. 23 Elm Grove-terrace, London-road, Salisbury.
1880. *Stevens, J. Edward, LL.B. 10 Cleveland-terrace, Swansea.
1886. ‡Stevens, Marshall. Highfield House, Urmston, near Manchester.
1892. §Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1889. ‡Stevenson, T. Shannon. Westoe, South Shields.
1882. ‡*Steward, Rev. C. E., M.A. The Polygon, Southampton.*
1890. *Steward, Rev. Charles J., F.R.M.S. Somerleyton Rectory, Lowestoft.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1887. *Stewart, A. H. New College, Oxford.
1892. §Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 12 Montgomerie-crescent, Kelvinside, Glasgow.
1887. ‡Stewart, George N. Physiological Laboratory, Owens College, Manchester.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1892. §Stewart, Samuel. Knocknairn, Bagston, Greenock.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.

Year of Election.

1876. ‡Stirling, William, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *Stocker, W. N., M.A., Professor of Physics in the Royal Indian Engineering College. Cooper's Hill, Staines.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
1845. *Stokes, Sir George Gabriel, Bart., M.P., M.A., D.C.L., LL.D., D.Sc., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1887. ‡Stone, E. D., F.C.S. The Depleach, Cheadle, Cheshire.
1862. ‡Stone, Edward James, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1886. ‡Stone, J. B. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, London, E.C.
1888. ‡Stone, John. 15 Royal-crescent, Bath.
1876. ‡Stone, Octavius C., F.R.G.S. 49 Bolsover-street, Regent's Park, London, N.W.
1883. ‡Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, London, W.
1857. ‡Stoney, Bindon B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1878. *Stoney, G. Gerald. 69 Seventh-avenue, Heaton, Newcastle-upon-Tyne.
1861. *Stoney, George Johnstone, M.A., D.Sc., F.R.S., M.R.I.A. 9 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. Kenwyn, Cintra Park, Upper Norwood, S.E.
1883. ‡Stopes, Mrs. Kenwyn, Cintra Park, Upper Norwood, S.E.
1887. ‡Storer, Edwin. Woodlands, Crumpsall, Manchester.
1887. *Storey, H. L. Caton, near Lancaster.
1873. §Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1884. §Storrs, George H. Fern Bank, Stalybridge.
1859. §Story, Captain James Hamilton. 17 Bryanston-square, London, W.
1888. *Stothert, Percy K. Audley, Park-gardens, Bath.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *Strachey, Lieut.-General Richard, R.E., C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, London, W.
1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1889. ‡Straker, Captain Joseph. Dilston House, Riding Mill-on-Tyne.
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.
1889. §Streatfeild, H. S. The Limes, Leigham Court-road, Streatham, S.W.
*Strickland, Charles. 21 Fitzwilliam-place, Dublin.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.

Year of Election.

1887. *Stroud, Professor H., M.A., D.Sc., College of Science, Newcastle-upon-Tyne.
1887. *Stroud, William, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1876. *Struthers, John, M.D., LL.D., Emeritus Professor of Anatomy in the University of Aberdeen. 24 Buckingham-terrace, Edinburgh.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. 116 Grosvenor-road, Highbury New Park, London, N.
1886. ‡Stuart, G. Morton, M.A. East Harptree, near Bristol.
1892. §Stuart, Morton Gray, M.A. Ettrickbank, Selkirk.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1888. *Stubbs, Rev. Elias T., M.A. 4 Springfield-place, Bath.
1885. §Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
1891. *Sudborough, J. J. 111 Stratford-road, Birmingham.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, London, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. §Sutherland, James B. 10 Windsor-street, Edinburgh.
1884. ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡Sutton, Francis, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1891. §Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1881. §Swan, Joseph Wilson, M.A. Lauriston, Bromley, Kent.
1862. *Swan, William, LL.D., F.R.S.E., Emeritus Professor of Natural Philosophy in the University of St. Andrews. Ardchapel, Helensburgh, N.B.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
1887. §Swinburne, James. 49 Queen's-road, Wimbledon, Surrey.
1870. *Swinburne, Sir John, Bart., M.P. Capheaton, Newcastle-upon-Tyne.
1885. ‡Swindells, Miss. Springfield House, Ilkley, Yorkshire.
1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1890. §Swinhoe, Colonel C. Avenue House, Oxford.
1891. §Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1889. §Sworn, Sidney A., B.A., F.C.S. St. Peter's School, York.
1883. ‡Sykes, Alfred. Highfield, Huddersfield.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. 17 Albert-square, Clapham, London, S.W.
1890. §Sykes, Joseph. 113 Beeston-hill, Leeds.

Year of Election.

1862. ‡*Sykes, Thomas. Cleckheaton.*
1887. *Sykes, T. H. Cheadle, Cheshire.
SYLVESTER, JAMES JOSEPH, M.A., D.C.L., LL.D., F.R.S., Savilian Professor of Geometry in the University of Oxford. Oxford.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1885. ‡Symington, Johnson, M.D. 2 Greenhill Park, Edinburgh.
1881. *Symington, Thomas. Wardie House, Edinburgh.
1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. Dragon House, Bilbrook, near Taunton.
1886. §Symons, W. H., F.I.C., F.R.M.S. 130 Fellowes-road, Hampstead, London, N.W.
1872. ‡*Synge, Major-General Millington, R.E., F.R.G.S. United Service Club, Pall Mall, London, S.W.*

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. The Crescent, Birmingham.
1871. §TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡*Tait, P. M., F.S.S. Hardwicke House, Hardwicke-road, Eastbourne.*
1890. ‡Talbot, Rev. E. S. The Vicarage, Leeds.
1891. ‡Tamblyn, James. Glan Llynvi, Maesteg, Bridgend.
1891. §Tanner, Colonel H. C. B. The Red House, Petersfield.
1890. ‡TANNER, H. W. LLOYD, M.A., Professor of Mathematics and Astronomy in University College, Cardiff.
1892. *Tansley, Arthur G. Trinity College, Cambridge.
1883. §Tapscott, R. L., F.G.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. Moseley, Owl's-road, Boscombe, Bournemouth.
1857. *Tate, Alexander. Longwood, Whitehouse, Belfast.
1890. ‡Tate, Thomas, F.G.S. 5 Eldon-mount, Woodhouse-lane, Leeds.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1886. ‡*Taunton, Richard. Brook Vale, Witton.*
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. ‡Taylor, George Spratt, F.C.S. 13 Queen's-terrace, St. John's Wood, London, N.W.
1881. *Taylor, H. A. 25 Collingham-road, South Kensington, London, S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. 17 Castlegate, Nottingham.
1887. ‡TAYLOR, Rev. Canon ISAAC, D.D. Settrington Rectory, York.
1879. ‡Taylor, John. Broomhall-place, Sheffield.
1861. *Taylor, John, M.Inst.C.E., F.G.S. 29 Portman-square, London, W.
1873. ‡TAYLOR, JOHN ELLOR, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1883. ‡Taylor, Michael W., M.D. Hatton Hall, Penrith.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A. Whixley Hall, York.

Year of Election.

1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡Teall, J. J. H., M.A., F.R.S., F.G.S. 28 Jermyn-street, London, S.W.
1879. ‡Temple, Lieutenant George T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡Temple, Sir Richard, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., M.P., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1882. §Terrill, William. 42 St. George's-terrace, Swansea.
1881. ‡Terry, Sir Joseph. Hawthorn-villa, York.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1887. ‡Tetlow, T. 273 Stamford-street, Ashton-under-Lyne.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, London, W.C.
1885. ‡Thin, Dr. George, 22 Queen Anne-street, London, W.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡Thiselton-Dyer, W. T., C.M.G., C.I.E., M.A., B.Sc., Ph.D., F.R.S., F.L.S. Royal Gardens, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1875. *Thomas, Christopher James. Drayton Lodge, Redland, Bristol.
1891. *Thomas, Miss Clara. Llwynmadoc, Garth, R.S.O.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. §Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1883. ‡*Thomas, Ernest C., B.A.* 13 *South-square, Gray's Inn, London, W.C.*
1884. ‡Thomas, F. Wolferstan. Molson's Bank, Montreal, Canada.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §Thomas, J. Blount. Southampton.
1892. §Thomas, J. C., B.Sc. Queen Elizabeth's Grammar School, Carmarthen.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1891. ‡Thomas, John Tubb, L.R.C.P. Eastfields, Newport, Monmouthshire.
1880. *Thomas, Joseph William, F.C.S. Drumpellier, Brunswick-road, Gloucester.
1883. ‡Thomas, P. Bossley. 4 Bold-street, Southport.
1883. §Thomas, Thomas H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. §Thomason, Yeoville. 9 Observatory-gardens, Kensington, London, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.

Year of Election.

1891. *Thompson, Beeby, F.C.S., F.G.S. 55 Victoria-road, Northampton.
1887. §Thompson, C. 15 Patshull-road, Kentish Town, London, N.W.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡Thompson, D'Arcy W., B.A., Professor of Physiology in University College, Dundee. University College, Dundee.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.
1859. ‡Thompson, George, jun. Pitmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡Thompson, Sir Henry. 35 Wimpole-street, London, W.
1889. ‡Thompson, Henry. 2 Eslington-terrace, Newcastle-upon-Tyne.
1883. *Thompson, Henry G., M.D. 8 Addiscombe-villas, Croydon.
Thompson, Henry Stafford. Fairfield, near York.
1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.
1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.
1883. *Thompson, Isaac Cooke, F.L.S., F.R.M.S. Woodstock, Waverley-road, Liverpool.
1891. ‡Thompson, J. Tatham. 23 Charles-street, Cardiff.
1861. *Thompson, Joseph. Riversdale, Wilmslow, Manchester.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1874. ‡Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. ‡Thompson, Silvanus Phillips, B.A., D.Sc., F.R.S., F.R.A.S., Professor of Physics in the City and Guilds of London Institute, Finsbury Technical Institute, E.C.
1883. *Thompson, T. H. Heald Bank, Bowdon, Manchester.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1889. *Thomson, James, M.A. 2 Florentine-gardens, Hillhead-street, Glasgow.
1868. §Thomson, James, F.G.S. 26 Leven-street, Pollokshields, Glasgow.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1891. §Thomson, John. 70A Grosvenor-street, London, W.
1890. §Thomson, J. Arthur. 30 Royal-circus, Edinburgh.
1883. ‡Thomson, J. J., M.A., F.R.S., Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1871. *Thomson, John Millar, F.C.S., Professor of Chemistry in King's College, London. 53 Prince's-square, London, W.
1886. ‡Thomson, Joseph. Thornhill, Dumfriesshire.
1863. ‡Thomson, Murray. 44 Victoria-road, Gipsy Hill, London, S.E.
1874. §Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1886. §Thornley, J. E. Lyndon, Bickenhill, near Birmingham.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Thomas. Dundee.
1883. §Thorowgood, Samuel. Castle-square, Brighton.
1845. ‡Thorp, Dr. Disney. Lypiatt Lodge, Suffolk Lawn, Cheltenham.
1881. ‡Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1881. *Thorp, Josiah. 87 Selborne-street, Liverpool.
1864. *Thorp, William, B.Sc., F.C.S. 24 Crouch Hall-road, Crouch End, London, N.

Year of Election.

1871. ‡Thorpe, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London, S.W.
1883. §Threlfall, Henry Singleton. 12 London-street, Southport.
1883. ‡*Thresh, John C., D.Sc. The Willows, Buxton.*
1868. ‡Thuillier, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.
1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *Tiddeman, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1874. ‡Tilden, William A., D.Sc., F.R.S., F.C.S., Professor of Chemistry and Metallurgy in the Mason Science College, Birmingham.
1873. ‡Tilghman, B. C. Philadelphia, U.S.A.
1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. ‡Tillyard, Mrs. Fordfield, Cambridge.
1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1891. §Todd, Richard Rees. Portuguese Consulate, Cardiff.
1889. §Toll, John M. Monkton Lodge, Anfield, Liverpool.
1887. ‡*Tolmé, Mrs. Melrose House, Higher Broughton, Manchester.*
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.
1864. *Tomlinson, Charles, F.R.S., F.C.S. 7 North-road, Highgate, London, N.
1887. ‡Tonge, Rev. Canon. Chorlton-cum-Hardy, Manchester.
1887. ‡Tonge, James. Woodbine House, West Houghton, Bolton.
1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1887. ‡Topham, F. 15 Great George-street, London, S.W.
1861. *Topham, John, A.I.C.E. 53 Annandale-road, Vanbrugh Hill, London, S.E.
1872. *Topley, William, F.R.S., F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1886. ‡Topley, Mrs. W. Hurstbourne, Elgin-road, Croydon.
1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.
1886. ‡Torr, Charles Walker. Cambridge-street Works, Birmingham.
1884. ‡Torrance, John F. Folly Lake, Nova Scotia, Canada.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *Trail, Professor J. W. H., M.A., M.D., F.L.S. University of Aberdeen, Old Aberdeen.
1883. ‡Traill, A., M.D., LL.D. Ballylough, Bushmills, Ireland.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1875. ‡Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡Traquair, Ramsay H., M.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1891. ‡Trayes, Valentine. The Hill, Abergavenny.

Year of Election.

1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. §Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡Trimen, Henry, M.B., F.R.S., F.L.S. Peradeniya, Ceylon.
1871. ‡Trimen, Roland, F.R.S., F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §Tristram, Rev. Henry Baker, D.D., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1884. *Trotter, Alexander Pelham. 22 Cottesmore-gardens, Victoria-road, Kensington, London, W.
1885. §Trotter, Coutts, F.G.S., F.R.G.S. 17 Charlotte-square, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *Trouton, Frederick T., M.A., D.Sc. Trinity College, Dublin.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1885. *Tubby, A. H. Guy's Hospital, London, S.E.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
Tuke, James H. Bancroft, Hitchin.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1887. ‡Tuke, W. C. 29 Princess-street, Manchester.
1883. ‡Tupper, The Hon. Sir Charles, Bart., G.C.M.G., C.B., High Commissioner for Canada. 9 Victoria-chambers, London, S.W.
1892. §Turnbull, Alexander R. Ormiston, Hawick.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1871. ‡Turnbull, William, F.R.S.E. Menslaws, Jedburgh, N.B.
1891. ‡Turner, Miss E. R. Ipswich.
1882. ‡Turner, G. S. 9 Carlton-crescent, Southampton.
1883. ‡Turner, Mrs. G. S. 9 Carlton-crescent, Southampton.
1888. ‡Turner, J. S., J.P. Granville, Lansdowne, Bath.
1886. *Turner, Thomas, A.R.S.M., F.C.S., F.I.C. Mason Science College, Birmingham.
1863. *Turner, Sir William, M.B., LL.D., D.C.L., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1890. *Turpin, G. S., M.A., D.Sc. 2 St. James's-terrace, Nottingham.
1883. ‡Turrell, Miss S. S. High School, Redland-grove, Bristol.
1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.
1884. *Tweddell, Ralph Hart. Meopham Court, Gravesend, Kent.
1886. *Twigg, G. H. Church-road, Moseley, Birmingham.
1847. ‡Twiss, Sir Travers, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1888. §Tyack, Llewellyn Newton. University College, Bristol.
1882. §Tyer, Edward. Horneck, Fitzjohn's-avenue, Hampstead, London, N.W.
1865. §Tylor, Edward Burnett, D.C.L., LL.D., F.R.S., Keeper of the University Museum, Oxford.
1858. *Tyndall, John, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Hon. Professor of Natural Philosophy in the Royal Institution, London. Hind Head House, Haslemere, Surrey.

Year of Election.

1883. ‡Tyrer, Thomas, F.C.S. Garden-wharf, Battersea, London, S.W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. §Unwin, Howard. Newton-grove, Bedford Park, Chiswick, London.
1883. §Unwin, John. Park-crescent, Southport.
1883. §Unwin, William Andrews. The Briars, Freshfield, near Liverpool.
1876. *Unwin, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institute, City and Guilds of London. 7 Palace-gate Mansions, Kensington, London, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡*Upward, Alfred.* 11 *Great Queen-street, Westminster, London, S.W.*
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. ‡Ussher, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, W. C. Dorchester-street West, Montreal, Canada.
1883. *VanSittart, The Hon. Mrs. A. A. Haywood House, Oakfield-road, Bromley, Kent.
1886. ‡Vardy, Rev. A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. 5 Gayton-road, Hampstead, London, N.W.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, London, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, London, W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §Veley, V. H., M.A., F.C.S. 22 Norham-road, Oxford.
1873. *Verney, Captain Edmund H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.
1883. *Verney, Mrs. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart. Lower Claydon, Buckinghamshire.
1883. ‡Vernon, H. H., M.D. York-road, Birkdale, Southport.
1864. *Vicary, William, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Major R. de, R.E. Care of Messrs. Cox & Co., 16 Charing Cross, London, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1883. *Vines, Sydney Howard, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1856. ‡Vivian, Edward, M.A. Woodfield, Torquay.
*Vivian, Sir H. Hussey, Bart., M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1891. §Vivian Stephen. Llantrisant.

1886. *Wackrill, Samuel Thomas, J.P. Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1890. ‡Wadsworth, George Henry. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Devizes, Wiltshire.

Year of Election.

1890. §Wager, Harold W. T. Yorkshire College, Leeds.
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.
1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡Wake, Charles Staniland. Welton, near Brough, East Yorkshire.
1892. §Walcot, John. 50 Northumberland-street, Edinburgh.
1884. ‡Waldstein, Charles, M.A., Ph.D. Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1873. ‡*Wales, James.* 4 *Mount Royd, Manningham, Bradford, Yorkshire.*
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1882. *Walkden, Samuel. The Thorne, Bexhill, near Hastings, Sussex.
1890. §Walker, A. Tannett. Hunslet, Leeds.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1885. ‡Walker, Charles Clement, F.R.A.S. Lillieshall Old Hall, Newport, Shropshire.
1883. §Walker, Mrs. Emma. 18 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
Walker, Frederick John. The Priory, Bathwick, Bath.
1891. §Walker, Frederick W. Hunslet, Leeds.
1883. ‡Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1890. ‡Walker, Dr. James. 8 Windsor-terrace, Dundee.
1885. ‡Walker, General J. T., C.B., R.E., LL.D., F.R.S., F.R.G.S. 13 Cromwell-road, London, S.W.
1866. *Walker, John Francis, M.A., F.C.S., F.G.S., F.L.S. 45 Bootham, York.
1855. ‡Walker, John James, M.A., F.R.S. 12 Denning-road, Hampstead, London, N.W.
1881. ‡Walker, John Sydenham. 83 Bootham, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, London, S.E.
1888. §Walker, Sydney F. 195 Severn-road, Cardiff.
1887. ‡Walker, T. A. 15 Great George-street, London, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1881. *Walker, William. 18 Lendall, York.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡Wallace, Alfred Russel, D.C.L., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.
1892. §Wallace, Robert W. 14 Frederick-street, Edinburgh.
1887. *Waller, Augustus, M.D., F.R.S. Weston Lodge, 16 Grove End-road, London, N.W.
1862. ‡*Wallich, George Charles, M.D., F.L.S., F.R.G.S.* 26 *Addison-road, North, Notting-hill, London, W.*
1886. ‡Walliker, Samuel. Grandale, Westfield-road, Edgbaston, Birmingham.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth, F.S.A. Westfield, Westfield-road, Edgbaston, Birmingham.
1883. ‡Walmesley, Oswald. Shevington Hall, near Wigan.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, Professor R. M., D.Sc. Heriot Watt College, Edinburgh.

Year of Election.

1883. ‡Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.
1862. ‡Walpole, The Right Hon. Spencer Horatio, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1887. ‡Ward, A. W., M.A., Litt.D., Principal of Owens College, Manchester.
1874. §Ward, F. D., J.P., M.R.I.A. Clonaver, Strandtown, Co. Down.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡Ward, H. Marshall, M.A., F.R.S., F.L.S., Professor of Botany in the Royal Indian Civil Engineering College, Cooper's Hill, Egham.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, F.S.A. Lenoxvale, Belfast.
1887. §Ward, John, F.G.S. 23 Stafford-street, Longton, Staffordshire.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. Red House, Ravensbourne Park, Catford, S.E.
1884. *Ward, John William. Newstead, Halifax.
1883. ‡Ward, Thomas, F.C.S. Arnold House, Blackpool.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1884. §Wardwell, George J. Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Pittsburg, Pennsylvania, U.S.A.
1878. §Warington, Robert, F.R.S., F.C.S. Harpenden, St. Albans, Herts.
1882. ‡Warner, F. W., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1875. ‡Warren, Algernon. 6 Windsor-terrace, Clifton, Bristol.
1887. ‡Warren, Major-General Sir Charles, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, London, S.W.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1875. *Waterhouse, Lieut.-Colonel J. 40 Hamilton-terrace, London, N.W.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1892. §Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1887. ‡Watkin, F. W. 46 Auriol-road, West Kensington, London, W.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1886. *Watson, C. J. Botteville-road, Acock's Green, Birmingham.
1883. ‡Watson, C. Knight, M.A. Society of Antiquaries, Burlington House, London, W.
1892. §Watson, G. 9 Victoria-chambers, South Parade, Leeds.
1885. §Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡Watson, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1887. ‡Watson, J. Beauchamp. Gilt Hall, Carlisle.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. 19 Bloomfield-terrace, Gateshead.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 23 Cross-street, Finsbury, London, E.C.
1892. §Watson, William, M.D. Slateford, Midlothian.

Year of Election.

1879. *Watson, William Henry, F.C.S., F.G.S. Analytical Laboratory, The Folds, Bolton.
1882. ‡Watt, Alexander. 89 Hartington-road, Sefton Park, Liverpool.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E., F.R.G.S. Ashley-avenue, Belfast.
1888. ‡Watts, B. H. 10 Rivers-street, Bath.
1891. *Watts, E. Hannay, F.R.G.S. Springfield, Newport, Monmouthshire.
1875. *Watts, John, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *Watts, W. Marshall, D.Sc. Giggleswick Grammar School, near Settle.
1883. §Watts, W. W., M.A., F.G.S. 14 Hume-street, Dublin.
1859. ‡Waugh, Edwin. New Brighton, near Liverpool.
1891. §Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. §Webb, Sidney. 4 Park-village East, London, N.W.
1866. *Webb, William Frederick, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1886. §Webber, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, London, S.W.
1891. §Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1882. *Webster, Sir Richard Everard, LL.D., Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, London, S.W.
1889. *Webster, William, F.C.S. 50 Lee Park, Lee, Kent.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Karlsruhe.
1889. ‡Weeks, John G. Bedlington.
1890. §Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.
1876. *Weldon, W. F. R., M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. 30A Wimpole-street, London, W.
1880. *Weldon, Mrs. 30A Wimpole-street, London, W.
1881. ‡Wellcome, Henry S. First Avenue Hotel, Holborn, London, W.C.
1879. §Wells, Charles A., A.I.E.E. Bridge House, Lewes.
1881. §Wells, Rev. Edward, B.A. West Dean Rectory, Salisbury.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1887. *Welton, T. A. Rectory House-grove, Clapham, London, S.W.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. 8 Great Cumberland-place, London, W.; and Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. §Wertheimer, J., B.A., B.Sc., F.C.S. Merchant Venturers' School, Bristol.

Year of Election.

1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1882. *Westlake, Ernest, F.G.S. 2 Ridgeway-road, Redhill.
1882. ‡Westlake, Richard. Portswood, Southampton.
1863. ‡*Westmacott, Percy. Whickham, Gateshead, Durham.*
1875. *Weston, Sir Joseph D., M.P. Dorset House, Clifton Down, Bristol.
1882. ‡Wethered, Edward, F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1884. ‡Wharton, E. R., M.A. 4 Broad-street, Oxford.
1885. *Wharton, Captain W. J. L., R.N., F.R.S., F.R.G.S. Florys, Prince's-road, Wimbledon Park, Surrey.
1888. ‡Wheatcroft, William G. 6 Widcombe-terrace, Bath.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.
1883. *Wheeler, George Brash. Elm Lodge, Wickham-road, Beckenham, Kent.
1878. *Wheeler, W. H., M.Inst.C.E. Boston, Lincolnshire.
1888. §Whelen, John Leman. 73 Fellows-road, London, N.W.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *Whidborne, Rev. George Ferris, M.A., F.G.S. St. George's Vicarage, Battersea Park-road, London, S.W.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1884. ‡Whischer, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1874. ‡Whitaker, Henry, M.D. 33 High-street, Belfast.
1883. *Whitaker, T. Savile Heath, Halifax.
1859. *Whitaker, William, B.A., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and 33 East Park-terrace, Southampton.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva, F.R.S.E., F.R.G.S., 22 Duke-street, Edinburgh.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Balruddery, near Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡White, John Forbes. 311 Union-street, Aberdeen.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 9 The Paragon, Blackheath, London, S.E.
1883. *White, Mrs. 9 The Paragon, Blackheath, London, S.E.
1886. *White, William. The Ruskin Museum, Sheffield.

Year of Election.

1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. 99 New John-street West, Birmingham.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1871. ‡*Whitelaw, Alexander.* 1 *Oakley-terrace, Glasgow.*
1884. ‡*Whiteley, Joseph. Huddersfield.*
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1866. ‡Whitfield, Samuel. Eversfield, Eastnor-grove, Leamington.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Canon C. T., M.A., F.R.A.S. Bedlington Vicarage, Northumberland.
1891. §Whitmell, Charles Thomas, M.A., B.Sc., F.G.S. 47 Park-place, Cardiff.
1857. *Whitty, Rev. John Irwine, M.A., D.C.L., LL.D. 1 Rodbourne-villas, Crescent-road, Ramsgate.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. Redland House, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡*Whitworth, Rev. W. Allen, M.A. Glenthorne-road, Hammersmith, London, W.*
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Sir Henry, Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1885. ‡Wigglesworth, Alfred. Gordondale House, Aberdeen.
1883. ‡Wigglesworth, Mrs. Ingleside, West-street, Scarborough.
1881. *Wigglesworth, Robert. Beckwith Knowle, near Harrogate.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1883. ‡Wigner, G. W. Plough-court, 37 Lombard-street, London, E.C.
1889. *Wilberforce, L. R., M.A. Trinity College, Cambridge.
1881. ‡Wilberforce, W. W. Fishergate, York.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *Wilde, Henry, F.R.S. The Hurst, Alderley Edge, Manchester.
1887. ‡Wilkinson, C. H. Slaithwaite, near Huddersfield.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1892. §Wilkinson, Rev. J. Frome. Kilvington Rectory, Nottingham.
1886. *Wilkinson, J. H. Corporation-street, Birmingham.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. The Polygon, Ardwick, Manchester.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1859. ‡Willet, John, M.Inst.C.E. 35 Albyn-place, Aberdeen.
1872. ‡Willett, Henry, F.G.S. Arnold House, Brighton.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, London, W.
1887. ‡Williams, E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1883. ‡Williams, Rev. H. A. The Ridgeway, Wimbledon, Surrey.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1888. ‡Williams, James. Bladud Villa, Entryhill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. The Cedars, Llandaff-road, Cardiff.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katherine. Llandaff House, Pembroke-vale, Clifton, Bristol.

Year of Election.

1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡Williams, Matthew W., F.C.S. Queenwood College, Stockbridge, Hants.
1891. §Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. North Brow, Primrose Hill, London, N.W.
1883. ‡Williams, T. H. 2 Chapel-walk, South Castle-street, Liverpool.
1883. §Williams, T. Howell. 58 Lady Margaret-road, London, N.W.
1888. ‡Williams, W. Cloud House, Stapleford, Nottinghamshire.
1877. *Williams, W. Carleton, F.C.S. Firth College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *Williamson, Alexander William, Ph.D., LL.D., D.C.L., F.R.S., F.C.S., Corresponding Member of the French Academy. High Pitfold, Haslemere.
1857. ‡Williamson, Benjamin, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
Williamson, William C., LL.D., F.R.S., Emeritus Professor of Botany in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, London, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1859. ‡Wilson, Alexander Stephen. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. ‡Wilson, Colonel Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. Ordnance Survey Office, Southampton.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1875. ‡Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1883. *Wilson, Henry, M.A. Farnborough Lodge R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1886. ‡Wilson, J. E. B. Woodslee, Wimbledon, Surrey.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1865. ‡Wilson, Rev. James M., M.A., F.G.S. Clifton College, Bristol.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1861. ‡Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.

Year of Election.

1887. §Wilson, W., jun. Hillock, Terpersie, by Alford, Aberdeenshire.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1861. *Wiltshire, Rev. Thomas, M.A., F.G.S., F.L.S., F.R.A.S., Assistant Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. §Windle, Bertram C. A., M.A., M.D., D.Sc., Professor of Anatomy in Mason College, Birmingham.
1887. ‡Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.
1863. *Winwood, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1888. ‡Wodehouse, E. R., M.P. 56 Chester-square, London, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1884. ‡Womack, Frederick, Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. 68 Abbey-road, London, N.W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡Wood, Sir H. Trueman, M.A. Society of Arts, John-street, Adelphi, London, W.C.
1883. *Wood, James, LL.D. Grove House, Scarisbrick-street, Southport.
1881. §Wood, John, B.A., F.R.A.S. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Woodbine Lodge, Scarisbrick New-road, Southport.
1886. ‡Wood, Rev. Joseph. Carpenter-road, Birmingham.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq., Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1890. *Wood, Robert H., M.Inst.C.E. 15 Bainbrigge-road, Headingley, Leeds.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *Woodall, John Woodall, M.A., F.G.S. St. Nicholas House, Scarborough.
1884. ‡Woodbury, C. J. H. 31 Devonshire-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodcock, T., M.A. 150 Cromwell-road, London, S.W.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, London, N.W.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1888. *Woodiwiss, Alfred. Belair, Trafalgar-road, Birkdale, Southport.
1888. *Woodiwiss, Mrs. Alfred. Belair, Trafalgar-road, Birkdale, Southport.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
*Woods, Edward, M.Inst.C.E. 6b Victoria-street, Westminster, London, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. Carlton House, 57 Hoghton-street, Southport.
Woods, Samuel. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
1888. ‡Woodthorpe, Colonel. Messrs. King & Co., 45 Pall Mall, London, S.W.

Year of Election.

1887. *Woodward, Arthur Smith, F.L.S., F.G.S., Assistant Keeper of the Department of Geology, British Museum (Natural History). Cromwell-road, London, S.W.

*Woodward, C. J., B.Sc. 97 Harborne-road, Birmingham.

1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, London, S.W.

1866. ‡Woodward, Henry, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.

1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.

1881. ‡Wooler, W. A. Sadberge Hall, Darlington.

1884. *Woolcock, Henry. Rickerby House, St. Bees.

1890. §Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.

1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.

1883. *Woolley, George Stephen. 69 Market-street, Manchester.

1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.

1874. ‡Workman, Charles. Ceara, Windsor, Belfast.

1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.

1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.

1855. *Worthington, Rev. Alfred William, B.A. Stourbridge, Worcestershire.

Worthington, James. Sale Hall, Ashton-on-Mersey.

1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.

1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.

1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, London, S.W.

1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.

1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.

1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.

1871. §Wright, C. R. A., D.Sc., F.R.S., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.

1857. ‡Wright, E. Perceval, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.

1886. ‡Wright, Frederick William. 4 Full-street, Derby.

1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.

1876. ‡Wright, James. 114 John-street, Glasgow.

1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.

1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.

1831. Wright, T. G., M.D. 91 Northgate, Wakefield.

1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.

1871. ‡Wrightson, Thomas, M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.

1887. ‡Wrigley, Rev. Dr., M.A., M.D., F.R.A.S. 15 Gauden-road, London, S.W.

1876. ‡Wunsch, Edward Alfred, F.G.S. Carharrack, Scorrier, Cornwall.

1892. §Wyld, Norman. University Hall, Edinburgh.

1892. §Wyld, Robert S., LL.D., F.R.S.E. 10 Inverleith-row, Edinburgh.

1883. §Wyllie, Andrew. 1 Leicester-street, Southport.

1885. ‡Wyness, James D., M.D. 53 School-hill, Aberdeen.

1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.

Year of Election.

1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
1883. §Yates, James. Public Library, Leeds.
1867. ‡Yeaman, James. Dundee.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, London, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, London, S.E.
1886. *YOUNG, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Frederick. 5 Queensberry-place, London, S.W.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1886. §Young, R. Fisher. New Barnet, Herts.
1883. *YOUNG SYDNEY, D.Sc., Professor of Chemistry in University College. Bristol.
1887. ‡Young, Sydney. 29 Mark-lane, London, E.C.
1890. ‡Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1868. ‡Youngs, John. Richmond Hill, Norwich.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, United States.
1892. Svante Arrhenius. The University, Stockholm.
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, United States.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 7, 6A, Germany.
1892. Professor M. Bertrand. L'École des Mines, Paris.
1880. Professor Ludwig Boltzmann. München.
1887. His Excellency R. Bonghi. Rome.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, United States.
1884. Professor H. P. Bowditch, M.D. Boston, Massachusetts, United States.
1890. Professor Brentano. Maximilian-platz, Munich.
1884. Professor George J. Brush. Yale College, New Haven, United States.
1887. Professor J. W. Bruhl. Freiburg.
1887. Professor G. Capellini. Royal University of Bologna.
1887. Professor J. B. Carnoy. Louvain.
1887. H. Caro. Mannheim.
1861. Dr. Carus. Leipzig.
1887. F. W. Clarke. United States Geological Survey, Washington, United States.
1855. Professor Dr. Ferdinand Cohn. The University, Breslau, Prussia.
1881. Professor Josiah P. Cooke. Harvard University, United States.
1873. Professor Guido Cora. 74 Corso Vittorio Emanuele, Turin.
1880. Professor Cornu. L'École Polytechnique, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, United States.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1864. M. Des Cloizeaux. Rue Monsieur, 13, Paris.
1872. Professor G. Dewalque. Liége, Belgium.
1890. Professor V. Dwelshauvers-Dery. Liége.
1870. Dr. Anton Dohrn. Naples.
1892. Professor F. Elfving. Helsingfors, Finland.
1876. Professor Alberto Eccher. Florence.
1892. Professor Léo Errera. The University, Brussels.
1874. Dr. W. Feddersen. Leipzig.
1886. Dr. Otto Finsch. Bremen.

Year of Election.

1887. Professor R. Fittig. Strasburg.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1856. Professor E. Frémy. L'Institut, Paris.
1887. Professor Dr. Anton Fritsch. The University, Prague.
1892. Professor Dr. Gustav Fritsch. The University, Berlin.
1881. C. M. Gariel, French Association for the Advancement of Science. 22 Rue Serpente, Paris.
1866. Dr. Gaudry. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1884. Professor J. Willard Gibbs. Yale College, New Haven, United States.
1884. Professor Wolcott Gibbs. Harvard University, Cambridge, Massachusetts, United States.
1889. G. K. Gilbert. United States Geological Survey, Washington, United States.
1892. Daniel C. Gilman. Johns Hopkins University, Baltimore, United States.
1870. William Gilpin. Denver, Colorado, United States.
1889. Professor Gustave Gilson. Louvain.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1876. Dr. Benjamin A. Gould. Cambridge, Massachusetts, United States.
1884. Major A. W. Greely. Washington, United States.
1892. Dr. C. E. Guillaume. Sèvres.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1876. Professor Ernst Haeckel. Jena.
1889. Horatio Hale. Clinton, Ontario, Canada.
1881. Dr. Edwin H. Hall. Baltimore, United States.
1872. Professor James Hall. Albany, State of New York.
1889. Dr. Max von Hantken. Budapesth.
1887. Fr. von Hefner-Alteneck. Berlin.
1877. Professor H. L. F. von Helmholtz. Berlin.
1887. Professor W. His. Leipzig.
1887. S. Dana Horton. New York.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. Utrecht.
1887. Dr. Oliver W. Huntington. Harvard University, Cambridge, Massachusetts, United States.
1884. Professor C. Loring Jackson. Harvard University, Cambridge, Massachusetts, United States.
1867. Dr. Janssen, LL.D. The Observatory, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. Villa Frisia, Aroza, Graubünden, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. Annapolis, United States.
1887. Professor C. Julin. Liége.
1876. Dr. Giuseppe Jung. 7 Via Principe Umberto, Milan.
1877. M. Akin Kàroly. 92 Rue Richelieu, Paris.
1862. Aug. Kekulé, Professor of Chemistry. Bonn.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tokio, Japan.
1873. Dr. Felix Klein. The University, Leipzig.
1874. Professor Dr. Knoblauch. The University, Halle, Germany.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
1887. Professor Dr. Arthur König. Physiological Institute, University, Berlin.
1887. Professor Krause. Göttingen.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.
1887. Lieutenant R. Kund. German African Society, Berlin.

Year of Election.

1887. Professor A. Ladenburg. Breslau.
1887. Professor J. W. Langley. 847½ Fairmount-street, Cleveland, Ohio, United States.
1882. Professor S. P. Langley, LL.D., Secretary of the Smithsonian Institution. Washington, United States.
1887. Professor Count Solms Laubach. Strasburg.
1887. Dr. Leeds, Professor of Chemistry at the Stevens Institute, Hoboken, New Jersey, United States.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
1887. Professor A. Lieben. Vienna.
1883. Dr. F. Lindemann, Professor of Mathematics in the University of Königsberg.
1877. Dr. M. Lindemann, Hon. Sec. of the Bremen Geographical Society. Bremen.
1887. Professor Dr. Georg Lunge. The University, Zurich.
1871. Professor Jacob Lüroth. The University, Freiburg, Germany.
1871. Dr. Lütken. Copenhagen.
1887. Dr. Henry C. McCook. Philadelphia, United States.
1867. Professor Mannheim. Rue de la Pompe, 11, Passy, Paris.
1881. Professor O. C. Marsh. Yale College, New Haven, United States.
1867. Professor Ch. Martins, Director of the Jardin des Plantes. Montpellier, France.
1887. Dr. C. A. Martius. Berlin.
1890. Professor E. Mascart, Membre de l'Institut. 176 Rue de l'Université, Paris.
1887. Professor D. Mendeléef. St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1887. Professor Lothar Meyer. Tübingen.
1884. Albert A. Michelson. Cleveland, Ohio, United States.
1848. Professor J. Milne-Edwards. Paris.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, United States.
1877. Professor V. L. Moissenet. L'École des Mines, Paris.
1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1887. E. S. Morse. Peabody Academy of Science, Salem, Massachusetts, United States.
1889. Dr. F. Nansen. Christiania.
1864. Herr Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. Washington, United States.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1887. Professor Noelting. Mühlhausen, Elsass.
1890. Professor W. Ostwald. Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, United States.
1890. Maffeo Pantaleoni, Director of the Royal Superior School of Commerce. Bari.
1887. Dr. Pauli. Höchst-on-Main, Germany.
1890. Professor Otto Pettersson. Stockholm.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. Washington, United States.
1887. Professor W. Preyer. The University, Berlin.
1887. Professor N. Pringsheim. The University, Berlin.
1886. Professor Putnam, Secretary of the American Association for the Advancement of Science. Harvard University, Cambridge, Massachusetts, United States.
1887. Professor G. Quincke. Heidelberg.

Year of Election.

1868. L. Radlkofer, Professor of Botany in the University of Munich.
1886. Rev. A. Renard. Royal Museum, Brussels.
1873. Professor Baron von Richthofen. Kurfürstenstrasse, 117, Berlin.
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